*RESEARCH ARTICLE*

## AN ASSESSMENT OF ECONOMIC SUSTAINABILITY OF COMMUNITY SOLAR PHOTOVOLTAIC SYSTEMS: A CASE OF KUNTIYANI AND UMODZI CBOs IN BALAKA AND MACHINGA IN MALAWI.

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| *Manuscript Info* | *Abstract* |
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Community Solar Photovoltaic (CSPV) system plays an important role in accelerating the utilisation of solar energy in the rural areas where there is no grid-electricity. The need to sustain CSPV systems economically is well documented and cannot be over-emphasised. CSPV systems are vital in their contribution towards supplying electricity for lighting, powering appliances and pumping water to education and health institutions and the community as a whole in Malawi. The aim of this study was to assess economic sustainability of installed CSPV systems at Kuntiyani and Umodzi Community Based Organisations (CBOs). This study examined the CSPV system essential component specifications, their final end-customer price trends, availability and associated Income Generating Activity (IGA) earnings. These attributes are the main determinants of long-term economic sustainability of CSPV systems.

This qualitative exploratory research used physical inspection, questionnaire and focus group discussions data collection instruments, secondary sources and non-probability sampling. The physical inspection data were compared with Malawi Bureau of Standards (MBS) solar PV system specifications and the variations between the data were described. The quantitative data were organised and generated into graphs showing essential components final end-customer price trends; and IGA earnings. The qualitative data were coded, described and interpreted with regard to component sources and logistics. This study found out that: the installed CSPV system essential components complied with the MBS specifications; final end-customer prices showed moderate increasing trends; there are no rural markets for solar PV system components; the roads leading to the CBOs are in poor condition; and cumulative net IGA earnings can finance replacement components.

The study concludes that the installed CSPV system essential component specifications, their final end-customer price trends and IGA earnings can ensure economic sustainability at Kuntiyani and Umodzi CBOs while sources and logistics impede economic sustainability due to lack of rural markets for solar PV components since the concept is new. The study recommends inspecting CSPV system components to ensure MBS specifications are maintained,

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introducing import duty on renewable energy products, improving rural access roads to attract private traders and creating more income generating activities to increase revenue.

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## Acronymns:-

| | |
|---|---|
| A | Ampere |
| AC | Alternating Current |
| ACP | African, Caribbean and Pacific Group of States |
| Ah | Ampere-hours |
| ADER | Association of Development of Rural Electrification |
| AIDS | Acquired Immune Deficiency Syndrome |
| AIRE | Appalachian Institute for Renewable Energy |
| ARE | Alliance for Rural Electrification |
| BARREM | Barrier Removal to Renewable Energy |
| BIF | Business Innovation Facility |
| BMS | Bulembu Ministries in Swaziland |
| BOS | Balance of System |
| BREP | Bangladesh Rural Electrification Programme |
| C/10 | Coulomb discharge rate of 10 hours |
| C/20 | Coulomb discharge rate of 20 hours |
| CARES | Community Renewable Energy Scheme |
| CBO | Community Based Organisation |
| CBOs | Community Based Organisations |
| CDSS | Community Day Secondary School |
| CEC | Clean Energy Collective |
| CEDP | Community Energy Development Programme |
| CES | Community Energy Scotland |
| CF | Compounding factor |
| CIF | Cost Insurance and Freight |
| CREBS | Clean Renewable Energy Bonds |
| CRED | Community Rural Electrification and Development |
| CSF | Critical Success Factor |
| CSPV | Community Solar Photovoltaic System |
| DB | Decibels |

| DBSA | Development bank of South Africa |
|---|---|
| DC | Direct Current |
| DC – AC | Direct Current - Alternative Current |
| DEA | Department of Energy Affairs |
| DECC | Department of Energy and Climate Change |
| DFID | Department for International Development |
| DME | Department of Minerals and Energy |
| DOE | Department of Energy |
| DRC | Democratic Republic of Congo |
| EEP | Energy and Environment Partnership |
| EDA | Exploratory Data Analysis Approach |
| ESCOM | Electricity Supply Commission |
| EU | European Union |
| FGDs | Focus Group Discussions |
| FF | Fill factor |
| FV | Future value |
| FKEC | Florida Keys Electric Cooperative |
| FOB | Free on Board |
| FRES | Foundation Rural Energy Services |
| GIZ | German International Cooperation |
| GoM | Government of Malawi |
| HIV | Human Immune Virus |
| Hr | Hour |
| HVD | High Voltage Disconnect |
| HVR | High Voltage Reconnect |
| Hz | Hertz |
| I | Inflation rate |
| ICT | Information Communication and Technology |
| IDCOL | International Development Company Limited |
| IEA | International Energy Agency |
| IGA | Income Generating Activity |
| IGAs | Income Generating Activities |
| $I_M$ | Maximum Operating Current |
| IP | International Protection |
| $I_{SC}$ | Short Circuit Current |
| ISP | Institutional Support Programme |
| IT | Information Technology |
| JCE | Junior Certificate of Education |
| km | Kilometre |
| kW | Kilowatt |
| kWh | Kilowatt-hour |
| kWp | Peak kilowatt |
| LED | Light Emitting Diode |
| LCOE | Levelised Cost of Electricity |
| LLC | Limited Liability Cooperation |
| LV | Low voltage |
| LVD | Low Voltage Disconnect |
| LVR | Low Voltage Reconnect |
| mA | Milli-amperes |
| MBS | Malawi Bureau of Standards |
| MDEA | Malawi Department of Energy Affairs |
| MERA | Malawi Energy Regulatory Authority |
| MK | Malawi Kwacha |
| MoH | Ministry of Health |

| MPPT | Maximum Power Point Tracker |
|------|------------------------------|
| MREAP | Malawi Renewable Energy Acceleration Programme |
| MSCE | Malawi School certificate of Education |
| MS | Malawi Standard |
| MUREA | Mulanje Renewable Energy Agency |
| mW | Megawatt |
| MWP | Minimum Warranty Period |
| mWp | Peak megawatt |
| N | Number of years |
| NCST | National Commission for Science and Technology |
| NPV | Net Present Value |
| NGOs | Non-Governmental Organisations |
| ODI | Overseas Development Institute |
| Pmax | Rated Peak Power |
| PPA | Power Purchase Agreement |
| PTA | Parents Teachers Association |
| PV | Photovoltaic |
| PV-ESCO | Photovoltaic- Electricity Supply Company |
| REN21 | Renewable Energy for 21$^{st}$ Century |
| RET | Renewable Energy Technology |
| RETs | Renewable Energy Technologies |
| SEC | Swaziland Electricity Company |
| SHS | Solar Home System |
| SMC | School Management Committee |
| SMUD | Sacramento Municipal Utility District |
| SPSS | Statistical Package for Social Sciences |
| STD | Standard |
| TCRET | Testing Centre for Renewable Energy |
| TEP | Tucson Electric Power |
| TV | Television |
| UEM | Universidade Eduardo Mondlane |
| UNESCO | United Nations Education Scientific and Children Organisation |
| UNDP | United Nations Development Programme |
| UK | United Kingdom |
| USA | United States of America |
| USA-EIA | United States of America Energy Information Administration |
| V | Voltage |
| VA | Volt-amperes |
| VDC | Village Development Committee |
| $V_M$ | Maximum Operating Voltage |
| $V_{OC}$ | Open Circuit Voltage |
| W | Watt |
| $W_P$ | Peak watt |
| % | Percent |
| $^o$C | Degrees Celsius |

## Chapter 1:-   Introduction

### 1.0   Background:-

Renewable energy resources occur naturally through interaction between the sun and the earth's surface and cannot be depleted. Examples of renewable energy resources are solar energy, hydro power, wind energy, wave energy and geothermal energy (MDEA, 2016). USA-EIA (2016) has projected that the outlook for energy use worldwide is showing rising levels of demand over the next three decades. This growing demand for energy has necessitated the world to position renewable energy resources among the main-stream sources of energy (REN21, 2016).

Apparently, in all regions of the world new markets for both centralised and distributed renewable energy are emerging (Ibid, 2016). In sub-Saharan Africa, solar energy is the most popular renewable energy resource (IEA, 2012). Energy from the sun is converted into electricity which can be used for lighting, heating and powering appliances using solar photovoltaic (PV) system technology (Konkle, 2014).

Approximately 1.2 billion people in the world do not have access to electricity especially in Asia - Pacific region and sub-Saharan Africa (REN21, 2016). In Malawi, one of the sub-Saharan countries, 10% of the population have access to electricity, which constitutes 37% of the urban and 2% of the rural population, respectively (IEA and World Bank, 2015). On the other hand, Malawi is endowed with renewable energy resources such as biomass, hydro, wind, geothermal and solar energy but their full potential is far from being realised (MDEA, 2016). Gamula, Hui and Peng (2013) reaffirmed that there are a number of renewable energy resources but their exploitation remains a challenge to meet the energy demand because of "inadequate human capacity building at all levels in Renewable Energy Technology (RET) products, services, installation and maintenance, marketing, lack of information or awareness among the population, prohibitive capital costs of RET products and lack of enforcement mechanisms for standards resulting in poor quality products on the market" (MDEA, 2016 p.30).

Gamula et al. (2013) mentioned wrong approaches in addressing the problem as another reason of underutilisation of the available renewable energy resources. For example, in Malawi harnessing of solar energy to generate electricity was being undertaken during the time of the missionaries, but the systems were not sustained by the local people once the missionaries left (Ibid, 2014). Similarly, CES and MUREA (2014) observed that in Malawi most renewable energy projects fail to sustain themselves after project financiers have pulled out or the projects have phased out because of lack of exit strategies, insufficient training and capacity building within the communities to ensure sustainability.

In Malawi, the rural population still needs to benefit from renewable energy resources especially solar energy because it is unlikely that they will be supplied to the national electricity grid in the foreseeable future (Gamula et al., 2013). The hydro-electricity generated from the Shire River is unreliable and insufficient hence not able to meet energy demand (Ibid, 2013). Chinnammai (2013) highlighted that the role of solar energy is not only significant but also unavoidable at this time when climate change effects are being experienced. However, in Malawi attention should be put on sustainability of solar PV systems especially for the rural population since they are generally facing energy supply challenges (Gamula et al., 2013). Sustainable development has been defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). One of the challenges of sustainable development is economic sustainability (CES and MUREA, 2014). The economic sustainability challenge is often discussed in terms of market based situations, investment recovery and general affordability (Frame et al., 2011).

In view of solar PV systems economic sustainability challenges, in 2014, Community Energy Development Programme (CEDP) installed pilot Community Solar PV (CSPV) systems across the country as one way of addressing this challenge. A CSPV system is a solar PV system with multiple individual owners living in the surrounding area to the solar PV system, sharing the costs and benefits. (Farrell, 2010). The CSPV system is the newest concept into the renewable energy arena for Malawi (Konkle, 2014).

According to Currie et al. (2012), the concept of CSPV system has been introduced in Malawi to accelerate the utilisation of solar energy to serve Malawian energy needs in the present and into the future. The CSPV system is a valuable asset and many countries are making efforts to sustain them (Chinnammai, 2013). Therefore, measures have to be taken that can improve economic sustainability of CSPV systems. The benefits of improving economic sustainability for a CSPV system are that good quality components are used, sufficient funds are available to purchase replacement components and reliable Income Generating Activities (IGAs) are undertaken to fund the components (CES and MUREA, 2014). Ibid (2014) highlighted that an ideal CSPV system should be sustained economically, environmentally and socially. This study was carried out from the perspective of economic sustainability. Economic sustainability was centered on quality of components, sufficient funds to purchase replacement components and reliable IGAs (CES and MUREA, 2014). This study also included availability of replacement components in terms of sources and logistics. The study collected data from Kuntiyani and Umodzi Community Based Organisations (CBOs).

Kuntiyani Community Based Organisation (CBO) is located in Balaka District with Mbela as the nearest trading centre. Umodzi CBO is located in Machinga District with Nsanama about 23 kilometres (km) away as the nearest trading centre. Both districts are located in the southern region of Malawi (see Figure 1.1). The two CBOs were among the 12 CBOs across the country selected to install CSPV systems supported by CEDP. The needs assessment for Kuntiyani CBO was done by the CEDP officer while that of Umodzi was done by University of Malawi - Polytechnic students. The CBOs were chosen based on remoteness, ability of the community to fundraise and risk of theft. Energy committee members were elected from the CBOs and underwent training in leadership and business skills before requesting funding from CEDP.



**Legend**

| Lakes | Main Road network | Forest area |
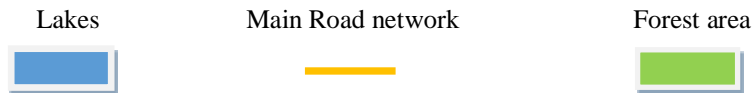
**Figure 1.1:-** Map of Malawi showing location of Kuntiyani and Umodzi CBOs in Balaka and Machinga districts respectively.

The CSPV systems at the two CBOs are system owner business models where funding for installation was a grant from CEDP but the CBOs operate and maintain the systems using earnings from IGAs. The CEDP officers assisted the energy committees in the procurement of RET contractors to design and install the CSPV systems. Figure 1.2 illustrates battery-based and water pumping CSPV systems at Umodzi and Kuntiyani CBO respectively. The CSPV system at Kuntiyani CBO consists of a 0.64-kilowatt (kW) solar PV water pumping system and 1 number (1no.) x 85 watts (W), 4no. x 170W and 1no. x 340W battery-based solar PV systems and were installed at a cost of thirty two million Malawi Kwacha (MK32,000,000). The CSPV system at Umodzi CBO consists of 1no. x 100W, 2no. x 160W, 2no. x 300W and 1no. x 600W battery-based solar PV systems and were installed at a cost of thirteen million Malawi Kwacha (MK13,000,000.00). The solar PV water pumping and battery-based systems at Kuntiyani were installed at Mpiniumodzi Primary School. The battery-based solar PV system at Umodzi CBO were installed at Mpiranjala Community Day Secondary School (CDSS), Mpiranjala Primary School and Namanja Health Centre.

**Figure 1.2:-** Battery-based and water pumping solar PV systems at Umodzi and Kuntiyani CBOs.

Battery-based solar PV systems consist of PV modules of either 80W, 85W or 100W, batteries of 96 ampere-hours (Ah), inverter of 600 volt-amperes (VA) and charge controller of either 15, 20 or 30 amperes (A) per set. The solar PV water pumping system consists of 8no. PV modules, 0.51kW water pump and 5W pump controller, 3no. x 5000 litre storage tanks. The energy committees set up IGAs in order to raise funds for operation and maintenance costs.

This study examined installed pilot CSPV system component specifications, their final end-customer price trends, availability and associated IGAs at Kuntiyani and Umodzi CBOs to ensure economic sustainability of the systems. The study also examined Income Generating Activity (IGA) earnings of both CSPV systems.

## 1.1 Problem Statement:-
In Malawi most solar PV systems were established by government or Non- Governmental Organisations (NGOs) and do not have any community level structures (Currie et al., 2012). The local people do not take care of the solar PV systems once the financiers move out. The lack of community level structures impede solar PV systems economic sustainability because there are no business plans to generate income for replacement of components within the communities (CES and MUREA, 2014). In view of this, CEDP developed Kuntiyani and Umodzi CBOs CSPV systems with defined community level structures to ensure economic sustainability. The CBOs were assisted with a grant to install CSPV systems and then were left to engage in IGAs for operation and maintenance costs of the systems. However, it is not known whether installed component specifications, final end-customer price trends, sources and logistics, and IGA earnings can enable the CBOs to economically sustain the installed CSPV systems or not as such stakeholders do not know the economic sustainability achieved through CSPV systems.

## 1.2 Objectives:-

*1.2.1   Main Objective*
The overall objective of the research was to examine the installed CSPV systems essential component specifications, final end-customer price trends, availability and associated income generating activities at Kuntiyani and Umodzi CBOs.

*1.2.2   Specific objectives*
The specific objectives of this research were to:
- (a)     assess compliance of the installed essential components to Malawi Bureau of Standards specifications;
- (b)     establish the final end-customer price trends for essential replacement components;
- (c)     establish the essential replacement component sources and logistics, and
- (d)     assess income generating activities' earnings.

## 1.3   Research Question and sub-questions:-

*1.3.1   Research question*
What are the installed CSPV system component specifications, final end-customer price trends, availability and associated income generating activities to ensure economic sustainability at Kuntiyani and Umodzi CBOs?

*1.3.2   Research sub-questions*
Specifically, this study attempted to answer the following research sub-questions:
- (a)     Are the installed components complying with Malawi Bureau of Standards specifications?
- (b)     What are the essential replacement component final end-customer price trends?
- (c)     What are the essential replacement component sources and logistics?
- (d)     Are income generating activities' earnings from CSPV systems capable of financing replacement of essential components?

## 1.4   Significance of the Study:-

According to CES and MUREA (2014), sustainability of CSPV systems targets three knowledge areas namely economic, social and environmental. The main focus of this study was economic sustainability knowledge area of CSPV systems in Malawi. The findings of this study will encourage stakeholders in the renewable energy sector of which CSPV systems are part to assess economic sustainability of community energy projects. In Malawi, one of the renewable energy policy statements is to enhance the involvement of community in planning and implementing energy projects in rural areas (MDEA, 2016). The study if shared with the Government of Malawi (GoM), through the Department of Energy, will encourage the department to make a paradigm shift from direct installation of renewable energy projects in rural areas to projects that involve the community; to ensure economic sustainability of the projects. Similarly, the study will also motivate the rural electrification program whose main focus was on expansion of the national grid electricity to selected rural areas but due to capacity constraints in Electricity Supply Commission (ESCOM)'s power system the GoM has incorporated renewable energy in its rural electrification program (MDEA, 2016). The CSPV system concept can play a vital role in increasing access to electricity in the rural areas. The study will also add value to, and encourage research work in solar PV system post-implementation and renewable energy as a whole.

## 1.5   Organisation of the dissertation:-

**Chapter 1** is an introduction, describing the problem at hand that is, lack of access to electricity and the manner in which this problem can be addressed. It highlights the potential the country has in terms of solar energy. It provides the optimal way of harnessing the solar energy to increase access to electricity. It then provides the measures that can be taken to sustain the CSPV systems economically.

**Chapter 2** is the literature review section of the report. The chapter presents experiences of different types of CSPV system business models and success factors in both developed and developing countries. The chapter also presents crucial elements of economic sustainability of these systems.

**Chapter 3** presents the methodology employed in the study. It focuses on research philosophy and approach; research strategy; target population and sampling procedure; data collection and analysis; validity and reliability;

and ethical consideration employed in the study. The chapter also presents reasons for the choice of the research methods.

**Chapter 4** presents the findings from the study and compares the findings with issues that emerged from the literature review. The chapter then discusses and summarises the findings to verify if the research questions have been answered.

**Chapter Five** presents findings of the study in relation to component standards, final end-customer price trends, sources and logistics, and IGA earnings. The chapter then makes conclusions derived from the study, and offers recommendations and direction for further study.

# Chapter 2:-   Literature Review
## 2.0   Introduction:-
This chapter presents experiences of different types of CSPV system business models and success factors in both developed and developing countries. The report considers studies that took place in USA, UK, Nigeria, Congo, Malawi, Kenya, Zambia, South Africa, Swaziland, Namibia, and other countries as stated in literature review. The chapter also presents crucial elements of economic sustainability of CSPV systems.

## 2.1   CSPV system in developed and developing countries:-
### 2.1.1   CSPV system ownership
Graham et al. (2008) categorised CSPV systems into three different types of ownership namely: system-owner, third-party and utility business models. Hou (2014, p.5) described business model as "the principles and logic how a company manages and operates business to generate revenues". CSPV system business models are the profit-earning business activities developed around the installed systems (Frantzis et al., 2008). Sub-sections 2.1.1.1, 2.1.1.2 and 2.1.1.3 present CSPV systems owned by individual, third-party and utility business models CSPV systems respectively. Performance, advantages and disadvantages of each model and comparisons between the models are also presented. It appears that CSPV systems are a promising solution for countries to meet demand for electricity services especially where there is no grid electricity (Davis, Currie and Young, 2011).

### 2.1.1.1   System-owner business model
System-owner business model is where the owner of the buildings uses power from the installed CSPV system and finances operation and maintenance of the system (Frantzis et al., 2008). This model is also referred to as zero generation solar PV business model (Ibid, 2008). The main focus of the system-owner business model is on manufacturing, supply and installation of solar PV systems (Hou, 2014, p.14). In some cases non-profit organisations such as schools and churches partner with local citizens to develop this kind of business model (Coughlin et al., 2010). Goel and Dwivedi (2010) highlighted that the model is popular to customers who are interested in energy security and the environment. In Washington, USA, Solar for Sakai at Bainbridge Island is an example of system-owner business model. Coughlin et al. (2010) reported that a 5.1kW system-owner business model was installed at Sakai Intermediate School by Community Energy Solutions, a non-profit making organisation. The funding for the model came from twenty-five community organisations or individuals tax-deductible donations in the USA (Ibid, 2010).

In Lagos, Nigeria, Adeyemo (2013) described two examples of system-owner business models. These were Bishop Kodji solar electrification project in Bishop's village and Onisowo village in Lagos respectively implemented by Lagos State Ministry under Lagos State Government (Ibid, 2013). The aim of the two projects was to supply water to the entire villages, street lighting for security and fish driers. Solar PV modules were mounted on the roof tops of either a mosque, church or community school (Ibid, 2013). The former project was a success and functioned well as planned, while the later only worked for about 3 months and stopped (Ibid, 2013). The Onisowo village project failed because of no proper planning for adequate funding for maintenance and sustainability of the project for the long-term (Ibid, 2013). In Democratic Republic of Congo, (Weimann, Ng and Lecoque, 2015) reported that Fondazione Madre Agnese Manzoni installed a solar PV, wind and hydro system to bring water in the hilly region of the lower Congo. The foundation met all the cost of purchasing equipment while the owners met transport and installation costs (Ibid, 2015). The owners were responsible for operation and maintenance costs through weekly contributions as payment to the water consumed (Ibid, 2015). The owners were also engaged in IGAs such as selling vegetables to meet operation and maintenance costs (Ibid, 2015).

In Malawi, Currie et al. (2012) described five different examples of system-owner business model as follows: Mikolongo Primary School CSPV system was implemented by Community Rural Electrification and Development (CRED), a Scottish funded project from January 2009 to late 2011. The main aim of the project was to improve the sustainability of rural solar PV system deployment in Malawi (Ibid, 2012). The system worked properly but could not generate enough funds for maintenance because community engagement, local responsibility and IGAs were not properly defined (Ibid, 2012). The project still depended on the funders through University of Strathclyde grants and University of Malawi -The Polytechnic for support (Ibid, 2012).

Choma Health Centre CSPV system was implemented by Ministry of Health (MoH) from 2005 to 2009 with funding from United Nations Development Programme (UNDP) (Ibid, 2012). The installed systems at the health centre were both battery-based and water pumping (Ibid, 2012). GoM installed the system to reduce deforestation in the area and attract and retain members of staff due to availability of electricity (Ibid, 2012). There was no community level structure as a result batteries were stolen immediately after installation and had never been replaced (Ibid, 2012). The solar water pump is still functioning but at reduced rate because of inconsistent servicing.

Solar villages - "Bringing the Town to the Village" large scale solar and wind hybrid system at Elunyeni in Mzimba and Chigunda in Nkhotakota project were implemented and funded by the GoM through the Department of Energy Affairs (DEA) from 2007 to 2008 (Ibid, 2012). The project's aim was to provide effective electricity systems for lighting and water pumping to remote locations with no grid electricity (Ibid, 2012). The structure of implementation was based on GoM contracts and the DEA was the project manager (Ibid, 2012). The roles and responsibilities of the community were not defined (Ibid, 2012).

Senga bay Baptist Medical clinic work on solar pumps CSPV system was implemented and funded by the Baptist Church from 2007 to 2009 (Ibid, 2012). The aim of the project was to use the solar electricity generated to pump borehole water for small scale irrigation schemes at two critical areas of service provision (Ibid, 2012). Baptist Church Ministry in Malawi was responsible for management of the systems (Ibid, 2012). Although the systems were functioning properly the roles and responsibilities were not given to communities to ensure long-term viability of the projects (Ibid, 2012).

Similarly, Milonde Youth Club Business Center CSPV system implemented by MUREA and Milonde Youth Club from 2007 to 2012 was a system-owner business model in Malawi (Ibid, 2012). The solar PV system was installed with funding from UNDP (Ibid, 2012). The project was established within the framework of decentralisation that recognises community participation in deciding development initiatives in their respective communities (Ibid, 2012). The main focus was to engage the youths in different IGAs to contribute towards poverty reduction (Ibid, 2012). IGAs included charging mobile phone batteries, video shows and other entertainment and operation of barber shops and salons (Ibid, 2012). The solar PV systems installed at the two business centres were functioning effectively especially in normal weather conditions (Ibid, 2012).

ACP-EU (2012) described another system-owner business model in Malawi as follows: Nsamala Sustainable Energy Project provided solar PV systems to rural schools and teachers houses (Ibid, 2012). The project was sponsored by the development cooperation between the European Union (EU) and the countries of the African, Caribbean and Pacific Group of States (ACP) energy facility (Ibid, 2012). The solar PV systems were given to the schools as grants after demonstrating ability to sustain them (Ibid, 2012). School Management Committee (SMC) or Parents Teachers' Association (PTA) were left with the responsibility of operating and maintaining the systems (Ibid, 2012). The committee administered operation and maintenance costs through members' contributions or IGAs (Ibid, 2012).

It can be summarised from the reports by ACP-EU (2012); Coughlin et al. (2012); Currie et al. (2012); and Adeyemo (2013) that system-owner business models are non-profit projects. The main focus is provision of the electricity for lighting or water pumping to the community (Adeyemo, 2013). It is also perceived from the reports that most of the system-owner business models are installed with funding from well-wishers or international organisations (Coughlin et al., 2010). The beneficiary community is responsible for operation and maintenance of the solar PV systems (ACP-EU, 2012). The system-owner business model brings benefits such as confidence, sense of ownership, and training in operation and maintenance skills to the system owners (CES and MUREA, 2014). Despite the benefits, ACP-EU (2012); and CES and MUREA (2014) outlined the following disadvantages of the system-owner business model: the beneficiaries require comprehensive training in technical, economic and social

capacity building; sustainability of the model might be affected by some people's influential behaviour; most beneficiaries are motivated by well-wishers or international organisations' support but over time financial and technical failures occur. It needs to first of all set up community level structures that will enable sustainability of the model before implementing the models which can be time consuming.

### 2.1.1.2   *Third-party business model*

Third-party or first generation business model is where the CSPV system is owned by a third-party who sells the electricity to the owner or the user of the building where the system is installed (Frantzis et al., 2008). The model enables customers to use solar PV systems without experiencing the trouble of high up-front costs and complexity to operate and maintain the system (Hou, 2014). In so doing, customers experience professional service in addition to increasing the useful lifespan of the solar systems (Ellegard, Arvidson and Nordstrom, 2004). In third-party model customers do not become owners of the systems (Ibid, 2004).

Coughlin et al. (2010) in their study reported about University Park Community Solar Limited Liability Corporation (LLC) in Maryland, USA. The project was a 22kW system installed on a roof of a local church in May, 2010 (Ibid, 2010). It was formed like a third-party business model that would return investment in 5 to 6 years. It was a 20 year agreement detailing the provision of electricity, access to solar array, maintenance, insurance and other issues (Ibid, 2010). The benefits were passed on to its members based on revenue such as electricity sold to the church and grid, federal tax incentives and depreciation (Ibid, 2010).

Oliphant (2012) reported about another third-party business model in Colorado, USA as follows: Community Energy Collective (CEC) enabled individuals to own solar PV systems in a community shared solar farm. A solar farm is solar PV array with multiple subscribers connected to the utility grid (Ibid, 2012). The aim of the project was to combine the on-bill credits of a utility-owned project with the equivalent tax benefits and rebates of an individually owned solar project (Ibid, 2012). Customers receive credits on their electricity bill for the energy produced less a charge to deliver the energy to the subscriber location (Ibid, 2012).

Wiemann et al. (2015) reported about two third-party business models as follows: In Mali, South Africa, Burkina Faso, Uganda and Guinea-Bissau, Foundation Rural Energy Services (FRES) supplies electricity from Solar Home Systems (SHS) and solar power plants to customers using the fee-for-service concept. The fee for SHS is paid monthly depending on the number of lamps and socket outlets chosen while customers for mini-grids pay connection fee and the amount of electricity consumed per kilowatt-hour (kWh). FRES companies in the various countries were responsible for installation and maintenance of the systems to ensure long term sustainability of the systems. In total 30252 customers were supplied with SHS by the end of 2013. In Mauritania about 8000 inhabitants (555 individual connections and 25 industrial connections) in the towns of Nebaguiya, Kser Torchane and El Gheduja were supplied with electricity from three mini solar-diesel hybrid power plants respectively. The project was financed by EU Energy Facility and the Mauritanian Government through Association of Development of Rural Electrification (ADER) which is responsible for managing the plants.

A pioneering community operated a solar PV system plant in a Kenyan village of Kitonyoni as a third-party business model. Pultarova (2013) in her report indicated that the plant supplies generated electricity to a school, health centre, churches and 40 businesses. The project was funded by the United Kingdom (UK)'s Research Council and Department for International Development (DFID). The local community was directly responsible for operating and maintaining the plant. The businesses were shareholders who generated income through membership fees.

Ellegard et al. (2004) reported about the Zambia Photovoltaic Electricity Supply Company (PV-ESCO) project third party business model in Eastern Province of Zambia. The model was operated by three companies with over 400 installed solar PV systems. In return customers were charged with a fee for using the systems. The fees covered operational and maintenance costs including replacement of the solar PV components. The systems were used for lighting and powering appliances such as television (TV) and radio. The systems also improved learning as they provided opportunities for people to attend evening studies in schools; and they opened up IGA opportunities such as phone charging and video shows.

Lemaire (2011) reported about a third-party solar PV system business model in South Africa. The Department of Minerals and Energy (DME) awarded a concession to NuRa, a private company to install solar PV systems to 25000 customers in 2005. Customers paid a small fee to get connected and a monthly pre-paid fee for electricity bills. The

model at first operated like small scale utilities but later turned into a large scale solar PV system due to fee-for-service concession. The concessionaire was responsible for all maintenance issues although the DME remained the owner of the solar PV systems.

From the literature by Ellegard et al. (2004); Coughlin et al. (2010); Lemaire (2011); Oliphant (2012); Pultarova (2013); and Wiemann et al. (2015) it can be summarised that third-party CSPV system business model is a profit oriented model. The cited reports have specifically illustrated two different types of third-party business models. The first type is where the community owns solar PV systems and sells the electricity to the utility grid under power purchase agreements (PPAs) (Coughlin et al., 2010 and Oliphant, 2012). The second type is where the community owns and operates solar PV systems at the customers' premises in return for a service fee (Ellegard et al., 2004; Lemaire, 2011; Pultarova, 2013; and Wiemann et al., 2015). In both cases the revenue generated is used for operational and maintenance costs and the profits are shared among shareholders (Ellegard et al., 2004; Coughlin et al., 2010; Lemaire, 2011; Oliphant, 2012; Pultarova, 2013; and Wiemann et al., 2015). In comparison with the system owner business model the third-party business model has the following advantages: "it reduces operation and maintenance burden for end-users, access to subsidies reduces up-front costs, identifies and mitigate technical risks because of competent technical personnel and benefit from all government incentives such as duty free status" (Hou, 2014 p.4-5). The disadvantages of the third-party model include: reduced demand without subsidies or incentives; economics of incentives transfers most risks to the third party; requires high competent technical and managerial personnel (Frantzis et al., 2008; ACP-EU, 2012; and Hou, 2014) and "long-term risks and lower returns" (Anderson et al., 2015 p.13).

### 2.1.1.3 Utility business model

Utility business or second generation business model is a system of ownership where the CSPV systems are integrated into the electricity supply and distribution infrastructure (Frantzis et al., 2008). Inskeep et al. (2015) and Tongsopit (2016) highlighted that utility business models provide renters and customers who cannot afford and those with unsuitable roof or leave the rooftop for solar thermal with opportunity to acquire solar PV system. In addition, the model offers better economies of scale (Iler, 2012). Utility business models are not common because of limited value in distributed solar PV systems (Frantzis et al., 2008). Barnes and Foley (2004) reaffirmed that capital and operating costs are very high for utility companies due to low population densities in the rural areas.

Coughlin et al. (2010); Farrell (2010); and Inskeep (2015) illustrated three different examples of solar PV system utility business models in the USA respectively. The first one is Sacramento Municipal Utility District (SMUD) under the Solarshare Programs (Coughlin et al., 2010). SMUD contracted EnXco to install a 1 megawatt (mW) utility business model and the electricity generated from the system was fed directly into the grid (Ibid, 2010). Customers paid a fixed monthly fee in return for the amount of solar PV system electricity subscribed (Ibid, 2010). There were about 700 residential customers (Ibid, 2010). EnXco sold the power to SMUD under a twenty-year PPA (Ibid, 2010). United Power installed a 10kW utility business model at Sol Partners Cooperative Solar Farm in Colorado (Ibid, 2010). Each customer leases a 210W solar PV system for 25 years (Ibid, 2010). These customers as usual got their monthly electricity bills less a credit for the amount of electricity from their solar PV system produce (Ibid, 2010).

The second one is Florida Keys Electric Cooperative (FKEC), a 96.6kW solar array constructed in 2008 with funding from Clean Renewable Energy Bonds (CREBs) (Farrell, 2010). FKEC allowed members of the cooperative to lease 175W solar PV system for 25 years (Ibid, 2010). In return, the customers were entitled to the retail value of the electricity produced for 25 years (Ibid, 2010). The utility retained control of renewable energy credits (Ibid, 2010).

The third one is Tucson Electric Power (TEP) who installed a rooftop solar PV system program of 3.5 mW (Inskeep, 2015). In this program customers were required to pay an enrolment fee before getting the solar PV system (Ibid, 2015). The utility installed, operated and maintained the system on the customers' roof tops (Ibid, 2015). Customers had the option to buy the system or opt-out of the program for a fee in case of house ownership transfers (Ibid, 2015).

In Swaziland, (Schultz, 2011) also reported about the Bulembu Photovoltaic grid-tied system implemented by Bulembu Ministries in Swaziland (BMS). The project was funded by the Ministry of Foreign Affairs of Finland and the Austrian Development Cooperation through Development Bank of South Africa (DBSA) and the Energy and

Environmental Partnership (EEP). The aim of the project was to reduce the burden of unpredictable electricity supply from Swaziland Electricity Company (SEC) and enormous monthly bills. BMS managed the implementation of the project and established various enterprises to provide support to orphans and vulnerable children. Operating costs were obtained from enterprises such as Bulembu Timber, Diary, Honey, Bakery and Tourism.

Tsumkwe Energy in Namibia is another example of a utility model (ACP-EU, 2011). The project has a capacity of 200kWp and feeds into an isolated mini-grid. The project was developed through partnership between the implementing non-governmental organisation, national power utility and local authority. Service provision and maintenance of the systems lies in the hands of the local authority.

Coughlin et al. (2010); Farrell (2010); ACP-EU (2011); Schultz (2011); and Inskeep (2015) have illustrated examples of utility business models in the USA, Swaziland and Namibia. The utility business model CSPV systems described are both residential rooftop and off-site. Utility business models performance is "more efficient, equitable, affordable and always informed by best science and experience" (NRDC, 2015 p.6) than system-owner and third-party business models. Utility business models also provide benefits such as professional services in generation and distribution system and collection of tariffs, easier access to financial resources through loans and potential to achieve economies of scale (ACP-EU, 2012). If the CSPV system is not working power can still be drawn from the utility grid where it is integrated (CES and MUREA, 2014). The disadvantages of utility business models include the following: "The beneficiaries have no stake in the ownership of the system" (Coughlin et al., 2010 p.8). The model is subjected to political interference, for example, resources are diverged to other political activities instead of reinvestment (ACP-EU, 2012). CES and MUREA (2014) indicated that utility grid business models are suitable where there is grid-electricity and connection to the grid is expensive. In Malawi no literature was found in connection with utility business models.

In summary, it appears that CSPV system business models are a promising solution for countries to meet the demand for electricity services especially where there is no grid- electricity (Davis et al., 2011). There is reliable supply of electricity because the CSPV systems business models discussed create more value for customers by developing IGAs to raise funds for operation and maintenance of the systems, than just installing a solar PV system on a house without defining the source of funding for operation and maintenance costs (Franztis et al. 2008). The sub-sections 2.1.1.1, 2.1.1.2 and 2.1.1.3 have discussed and compared three types of CSPV systems business models, their performance, advantages and disadvantages. At this point, it is necessary to identify and discuss ways of sustaining the CSPV system business models.

**2.2   CSPV system business models' critical success factors:-**
Reilkoff (2016) described critical success factors (CSF) as elements that are necessary for an organisation or project to achieve its goals and mission. Dornan (2011 p.798) asserted that "although there are success stories, no 'perfect' institutional model for solar-based rural electrification has emerged but rather, the appropriateness of each model seems to depend on social, economic, political and cultural features of the community where systems are installed". This study identified good policies, community acceptance, long-term plans, community involvement, capacity building and favourable financial arrangements as some of the CSFs of CSPV systems business models.

*2.2.1   Effective policies*
Seyfang, Park and Smith (2013) revealed that for governments to achieve a low carbon energy system they need to consider CSPV systems business models. For example, Urmee and Harries (2012) reported that governments should be willing to subsidise solar PV system components to increase adoption of the models. Seyfang et al. (2013 p. 988) indicated that "there is a limit to how much community groups can achieve on their own"; and indicated that for the models to progress, consistent policy support is required to ensure availability of resources they need.

Pandey et al. (2012) reported that the Rajasthan Government India issued a Solar Energy Policy in 2011. The main objective of the policy was to promote off-grid solar PV systems and in particular development of CSPV system business models. In Kenya, past governments policies allowed duty and tariffs waivers on all solar PV system components and increased adoption rate of the technology. In Gambia, Sanneh and Hu (2009) affirmed that the decentralised policy was a viable alternative to promote Renewable Energy Technologies (RETs) in remote places. In Malawi, all renewable energy products are duty free (ODI, 2016).

### 2.2.2 *Community acceptance*

Although Frame et al. (2011) proposed community based approach for improved sustainability of renewable energy projects in Malawi and Gambia, this depends on community acceptance. "Community acceptance refers to the specific acceptance by local stakeholders, particularly residents and local authorities to make decisions on a particular project" (Wustenhagen et al., 2007 p.2685). Community acceptance is one of the three dimensions of social acceptance of renewable energy innovation (Ibid, 2007). There are three factors that influence community acceptance namely distributional justice, procedural justice and trust (Ibid, 2007). Distributional justice is related to how costs and benefits are shared while procedural justice is a fair decision making process that allows participation of all relevant stakeholders in the community (Gross et al., 2007). Trust is related to the local community: how they trust information and intentions of the investors and actors from outside the community (Huijts et al., 2007).

In the CSPV system business models discussed previously community acceptance is embraced, for instance, members' contributions to raise income to install, operate and maintain CSPV systems, PPAs in third party and utility business models, sharing of benefits and installing and operating solar PV systems on clients properties. Another good example is Solar for Sakai at Bainbridge Island in Washington, USA, where 25 communities or individuals funded the project from tax-deductible donations (Coughlin et al., 2010).

### 2.2.3 *Long-term planning*

Long-term planning is one of the CSPV system business model CSFs for sustainability of the models. The system-owner business model is affected by lack of skills and potential disputes therefore long-term preparation periods help in compensating such issues. Terrapon-Pffaff (2014) alluded that in developing countries long-term planning for small scale solar PV systems (10 - 50 peak-Watt (Wp)) are determined by community management models, financial mechanism and geographical location. In implementing third party and utility business models, long-term plans are regarded as a means of attracting private sector participation (ARE, 2014). For example, the University Park Community Solar LLC in Maryland in the USA planned to get return on investment between 5-6 years and signed 20 year agreement with the local church where the system was installed (Coughlin et al., 2010). Similarly, the Solarshare project in Ontario, Canada, signed 20 year power PPA with the Ontario Power Authority to sell the generated electricity (Oliphant, 2012); and the FKEC members of the cooperatives in the USA leased solar PV systems for 25 years (Farrell, 2010).

### 2.2.4 *Community involvement*

Soshinskaya et al. (2014) elaborated that community involvement in decision making for CSPV systems is important because it fosters trust and cohesiveness among stakeholders. In developing countries especially in sub-Saharan Africa, unfortunately, there is limited impact towards sustainability of solar PV systems because of absence of community involvement (Barnes and Foley, 2004). ARE (2014) indicated that long-term sustainability of business models depends on users' satisfaction, therefore, projects must respect local and traditional leaders. Davis et al. (2011) reported that most CSPV systems deployed in Malawi fail because of little or no community involvement at all or lack of on-going sustainability plan to improve remote community service infrastructure. For example, Mikolongo Primary School and Choma Health Centre CSPV systems in Malawi failed because of lack of community involvement (Currie et al., 2012). In another development, Rahman et al. (2013) described the Bangladesh Rural Electrification Program (BREP) as a positive case among developing countries where community participation was one of the key CSFs.

In solar PV system programs, community involvement helps assess the need for electricity, educates consumers in advance, encourages and promotes dissemination of the program (Barnes and Foley, 2004). In addition, in Bangladesh meetings to resolve disputes over land issues for a rural electrification program were done in advance before the arrival of the electricity supply (Ibid, 2004). In Thailand community groups made their own decision to make contributions in cash or kind towards a rural electrification program (Ibid, 2004). In Ireland, Parish Rural Electrification Committees helped utility companies in recruiting customers and this contributed to rapid implementation of the program (Ibid, 2004).

### 2.2.5 *Capacity building*

Capacity building in terms of adequately training both the users and local technicians is required to successfully implement CSPV systems (Brooks and Urmee, 2009). For example, in Malawi an installed CSPV system stopped

functioning soon after the project was completed because beneficiaries lacked technical skills required to maintain the system (MDEA, 2003). Konkle (2014) argued that CSPV systems sustainability can only be achieved by engaging professionals in RETs to design, install, operate and maintain the systems. For example, in Scotland, Kilbirne Solar PV and Thermal systems third-party business models were successful because professional consultants were engaged to provide technical support to the installer (CES, 2010). Brooks and Urmee (2009) reiterated that the most basic requirements for successful training are that the training reaches to the right people at the right time and delivers the right content.

"Solar PV system provides the opportunity to target different income levels by varying capacity" (Harrison et al., 2016 p.6). The system capacity for system-owner, third-party and utility business models ranges from 1.5 peak-kilowatt (kWp) to 4.1 kWp, 100 kWp to 1 peak-megawatt (mWp) and greater than 1 mWp respectively (Franztis et al., 2008). The small system capacity for system-owner business model permits the owners to be trained in operation and maintenance skills that are required to sustain the CSPV systems (Ibid, 2008). In most cases, system-owner business model depends on well-wishers and willingness of the owners to engage in IGAs for operation and maintenance costs (Ibid, 2008). In addition, IGAs like phone charging cannot generate adequate funding for operation and maintenance costs unless the CSPV system lighting is used to increase the time available for other IGAs such as shop selling at night (Ibid, 2008). Therefore, system-owner business model cannot afford to engage professional consultants and contractors to provide technical support unlike third-party and utility models (Ibid, 2008).

### 2.2.6   *Favourable financial arrangements*
Konkle (2012) disclosed that high up-front costs frighten many people from installing and maintaining their own CSPV systems. CES and MUREA (2014) highlighted that most CSPV systems fail as a result of insufficient funds to operate and maintain the systems. The success of any CSPV system business model lies on users' willingness to pay, reliable IGAs, and clear agreements (Ibrahim et al., 2002). Therefore, project implementers should make arrangements for operation and maintenance fund when adopting any business model.

The CSPV business models discussed in Section 2.1 have demonstrated different financial arrangements depending on the type of model. For example, funding for the Sakai Intermediate School system-owner business model in USA came from twenty-five communities or individuals donations (Coughlin et al., 2010). On the contrary, for Onisowo system-owner business model in Nigeria, no proper planning for operation and maintenance funding were made. As a result, the system only worked for 3 months (Adeyemo, 2013). The CEC third-party business model in the USA was funded with bridge loans from solar bond holders (Oliphant, 2012). In Zambia, the Zambia PV-ESCO introduced a fee-for-service arrangement for operation and maintenance costs (Ellegard et al., 2004). Similarly, with utility CSPV system business models like the SMUD in the USA, customers paid a fixed monthly subscription for the electricity used (Coughlin et al., 2010). The general lesson from the business models is that favourable financial arrangements is the critical factor that determines sustainability of such programs (Dornan, 2011). Therefore, arrangements for financial resources for maintenance of the business models should be explored adequately.

## 2.3   Comparison of installed CSPV systems in developed and developing countries:-
### 2.3.1 *Similarities*
The general consensus among the CSPV systems in developed and developing countries is that the local level community structure takes ownership and responsibility for managing the system with own rules developed after the projects were phased out (Frantzis, 2008; Schultz, 2011; and ACP-EU, 2012). The operating and maintenance costs of the systems are realised through contributions by members or IGA earnings (Coughlin et al., 2010; ACP-EU, 2012; and Weimann et al., 2015). For the community solar PV systems that failed, the reports highlighted that during the inception of the projects there were no long-term maintenance plans put in place for the systems (Currie et al., 2012 and Adeyemo, 2013). It was also indicated that community members were not exposed to pre-development or construction expenses as funding was sourced from elsewhere (Lemaire, 2011; Schultz, 2011; Pultarova, 2013; and Hou, 2014).

### 2.3.2   *Differences*
The differences between developed and developing countries' CSPV systems are that firstly, in developed countries, CSPV systems were created as business models and rely on income generated from membership contributions. For example University Park community solar LLC in Maryland in the USA, the generated electricity is sold to the church and the remainder to the national grid (Coughlin et al., 2010). In developing countries for example, Malawi,

CSPV systems are mostly installed at public institutions like schools and health centers (Coughlin et al., 2010; Currie et al., 2012; and Pultarova, 2013). Secondly, developed countries' CSPV systems sell their electricity to utility bodies through long-term power purchase agreements. In developing countries, the CSPV system electricity is used for own use, and it relies on IGA earnings for operation and maintenance costs (ACP-EU, 2012; Currie et al., 2012; and Adeyemo, 2013).

**2.4    Crucial elements of CSPV systems economic sustainability:-**
Solar PV system components standards, final end-customer prices, sources and logistics, and IGAs are fundamental elements to economic sustainability of CSPV systems (CES and MUREA, 2014).

*2.4.1    Solar PV system components and standards*
*2.4.1.1    Solar PV system components*
Solar PV system components are the different parts that work together to make up a solar PV system (Youngren, 2011). The essential battery-based solar PV system components are PV module, battery, charge controller and inverter (Frasz, 2013).   Solar water pumping system comprises PV module, water pump, control unit and storage tanks as essential components. Frasz (2013) described the individual battery-based solar PV components as follows: PV modules convert solar energy into electricity. Inverters transform direct current into alternating current. Batteries store energy in stand-alone applications for use at times when no irradiance is available. The rest of the components are called Balance of system (BOS) (wire, conduit, fusing, grounding, disconnects, meters, monitors) and all are additional elements necessary in order to properly install the PV system. Youngren (2011) pointed out that performance and reliability of the solar PV system depends on the proper integration of components into a complete system. Figure 2.1: illustrates battery-based and water pumping solar PV systems.
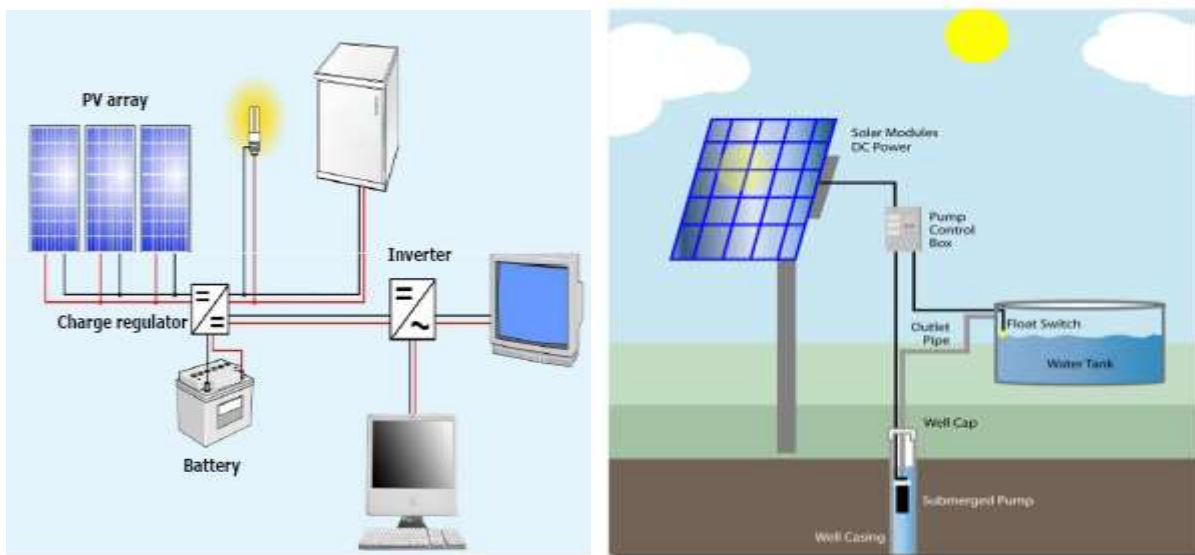


**Figure 2.1:-** Battery-based and water pumping solar PV systems (Source: Germi Energy Blog)

Urmee and Harries (2011) learnt that the success of the program depends on the ability of program implementers to maintain the quality of the solar PV system components. However, government policy support like subsidies, duty and tariffs waivers on solar PV systems components has both positive and negative effects. For example, Yu, Popielek and Geoffron (2014) indicated that government policy supports lead to increase in demand of solar PV systems components, but at the same time contribute to sub-standard components due to massive production. Similarly, in Malawi the removal of duty on all RET products has also resulted into inflow of low quality and counterfeit solar PV system products especially in cities and towns (ODI, 2016). CES and MUREA (2014) also disclosed that money is wasted in trying to fix and maintain solar PV systems that were designed poorly in the first place.

*2.4.1.2    Solar PV system components standards*
According to (Brazier, 2009 p.9) "Standards are agreed specifications for products, processes and services". Solar PV system components standards are described as "living documents that are frequently revised and updated as

experience is gained with solar PV systems". Ibid (2009 p.9) also revealed that standards contain requirements and best practice advice. "To "comply" with a standard you must meet the requirements, but you may choose to comply with the best practice advice". In developing countries especially sub-Saharan Africa the importance of proper component selection and whole system integration for long-term performance of off-grid solar PV system should be highlighted. For example, Younger (2011) reported that eleven African off-grid PV systems were inspected and found to have similar deficiencies in system configuration, materials used and installation methods in relation to solar PV modules, batteries, inverter, charge controller and BOS. Similarly, Ismail, Aide and Akingbesote (2012) embarked on a performance assessment of installed solar PV system in Oke-Agunla, Akure Ondo state in Nigeria after realising that the benefits expected from using these systems were jeopardised in some villages. People were interviewed and equipment on the ground were examined. Identification data on them was used to trace both functional and non-functional facilities to the manufacturers. The results of the assessment showed that solar PV system components used were inadequate.

Nkhonjera and Wu (2013) in a study that was conducted to analyse performance of SHS in low and high insolation areas of Malawi confirmed the importance of adhering to proper component standards and system integration as follows: good performance of the system is as a result of correct design in accordance to procedures stipulated in Malawi Standards (MS) (Ibid, 2013). Reduced performance ratio and less reliability occurs when the system is under-designed (Ibid, 2013). Khan, Rahman and Azad (2012) discussed the standard qualification testing procedure of solar PV components in Bangladesh perspective. Their discussion came about after they had seen that demand for solar PV system components increased due to a proliferation of SHS in Off-grid areas. They presented the testing procedures which were used to determine whether the SHS components met the Infrastructure Development Company Limited (IDCOL) standards. The major IDCOL requirements and findings for solar PV modules, batteries and charge controllers were as illustrated in Appendix A - Table A1.

### 2.4.1.3 Malawi Standards for essential solar PV system components
In Malawi, similar to the Bangladesh situation, there is an inflow of counterfeit solar PV system components on the market due to the recent trend of increase in demand of solar PV system products (CES and MUREA, 2014; ODI, 2016). Malawi Energy Regulatory Authority (MERA) and Malawi Bureau of Standards (MBS) are two bodies in Malawi that minimise inflow of counterfeit products through relevant conformity assessment programs (IOS, 2017). MERA is responsible for issuing of importation, selling, installation and maintenance licenses of solar PV system components while MBS is responsible for issuing of import certificates for products to ensure national standards are followed (MDEA, 2016). MERA also requires that "all licensed suppliers should offer consumers at least a one-year warranty and provide product information on the packaging." (BIF, 2014 p. 5). For consumer protection and quality assurance, RET suppliers are required to register with MERA to import and sell solar PV system components in the country, and MBS have to approve the components before they enter into the country (ODI, 2016).

However, MERA and MBS do not have adequate capacity to enforce the standards despite having explicit quality standards for the essential solar PV system components (ODI, 2016). The lack of testing facilities is another problem as the Testing Centre for Renewable Energy Technologies (TCRET) at Mzuzu University is not yet operational. The use of poor quality standard or counterfeit solar PV system components affects performance of the system to the extent that the project can be packed soon after completion of the installation (Sambo et al., 2014).

The Department of Energy through Barrier Removal to Renewable Energy in Malawi (BARREM) developed MS solar PV battery-based and solar PV water pumping systems. "The standards assist companies and inspectors ensure that proper components are installed on the systems, and inspect the systems according to specifications respectively" (MS 695, 2004 p. 1; MS 780, 2007 p.1). The Malawi Standard Solar PV systems battery-based and water pumping specifications are shown in Appendix A -Table A2 and Table A3 respectively.

### 2.4.2 Solar PV system components final end-customer prices
It is difficult to understand the coherent shifts occurring across the solar PV system industry with regard to solar PV system components final end-customer prices (Candelise, Winskel and Gross, 2013). Solar PV system components final end-customer price is the component prices charged to the final end-customer, resulting from a combination of production costs and 'companies' mark up (Ibid, 2013). This study illustrates results of different studies on solar PV system components final end-customer price reductions, trends and drivers. It has been observed from various studies that although the final end-customer prices of PV modules have declined globally, installed solar PV system

components final end-customer price reductions depend on several factors such as non-module costs, installation labour, local policies and location of the solar PV system.

### 2.4.2.1   Solar PV system components final end-customer price trends

Brazilian et al. (2013) narrated that solar PV system electricity is still expensive as compared to conventional electricity because of high components final end-customer prices. In contrast to this, (Candelise et al., 2013) reported that over the last decade, solar PV system components final end-customer prices have been unpredictable with increases or plateaus followed by rapid reductions.

Several studies have highlighted solar PV system components final end-customer prices trends. For example, Barbose et al. (2013) analysed project-level data for more than 200,000 individual residential, commercial and utility-scale solar PV systems installed in 2012. The main focus of the analysis was on the solar PV components final end-customer prices (Ibid, 2013). The number of solar PV system installed in the USA had grown at a rapid pace in the recent years. The rapid growth was driven in large measure by government incentives to encourage solar PV components final end-customer price reductions over time (Ibid, 2013). The price reductions were also associated primarily with a decline in non-module costs from 1998 to 2005 (Ibid, 2013). The non-module costs consist of a variety of component costs that are readily affected by local policies (Ibid, 2013).   Similarly, Reichelstein and Yorston (2012) provided a comprehensive assessment of the cost competitiveness of solar PV system installations as a result of the rapid growth of this type of electricity in recent years. The assessment was based on the data available for the second half of 2011 in certain parts of the USA. It was observed that the advocates of solar PV system electricity saw the rapid growth of the industry and dramatic drop in the final end-customer prices of PV modules as evidence of increasing competitiveness of this electricity (Ibid, 2012). In contrast to Barbose et al., 2013; Reichelstein and Yorston (2012) found out that the rapid rise of solar PV system electricity is attributed primarily to generous public policies in the form of tax subsidies and direct mandates for renewable energy, as well as ideal geographic location for the solar PV system installation.

Feldman (2014) also reported about progress in solar PV system reductions to help the USA Department of Energy (DOE) Sunshot Initiative and other stakeholders manage the transition to a market driven solar PV system industry. The study was conducted to provide clarity surrounding the wide variety of potentially conflicting data available about solar PV system prices. The analysis was based on 150,000 USA solar PV systems installed from 1998 through year end 2011 (with preliminary data for systems installed during first half of 2012). The results were that historical, recent and projected near term solar PV system final end-customer pricing trends in the USA showed substantial reductions over time and variability depending on system size, configuration and location. Krautmann and Zhu (2012) analysed the solar PV system market in the USA in order to inform the reader of the market trends within the photovoltaic solar industry (Ibid, 2012). It was realised in the analysis that the world today uses more energy than before, therefore, the global society must find more renewable and efficient sources of energy (Ibid, 2012). The use of solar PV systems had increased over the past few years due to rising cost of electricity, decrease in the solar PV system component final end-customer prices, federal and state incentives (Ibid, 2012).

In this literature, Barbose et al. (2013) agrees with Brazilian et al. (2013); Feldman et al. (2012); Krautmann and Zhu (2012); and Reichelstein and Yorston (2012) that there has been a decline in solar PV system final end customer prices in recent years. The rapid growth of solar PV systems is attributed to local policies of the area where the solar PV system is installed rather than global markets. This was observed in Barbose et al. (2012) in which non-module costs were affected by local policies in a particular period. In Africa, Caribbean and Pacific countries which include Malawi, the situation is that the final end-customer price trends of solar PV system components shows increasing tendency because the products are imported from industrialised countries (The ACP-EU, 2011). For example, the solar buzz retail module price index has decreased from 5.4 United States dollars (US$) to 3.1(US)$ per watt peak but in these countries, the Cost of Freight (CIF) and other costs have to be included on the final end-customer prices of solar PV system components.

### 2.4.2.2   Causes of Solar PV system components final end-customer price reduction

Goodrich, James and Woodhouse (2012) reported that component final end-customer price reductions are not necessarily realised in a timely manner by many customers. The quality of reporting and information on the solar PV system industry economics vary widely (Brazilian et al., 2013). It appears decision makers in the industry do not recognise this shift regarding current solar PV system components final end-customer prices and associated market and technology (Brazilian et al., 2013).

Regarding causes of final end-customer price reduction, Candelise et al. (2013) described and considered the causes of recent changes in solar PV system costs and final end-customer prices at module and system level. In the study both international trends and more specific contexts were considered. Other studies illustrated the use of forecasting methods to analyse cost reduction for PV module costs. The use of forecasting methods provides reliable cost reduction data as opposed to commonly used industry rule of the thumb of 5% module price drop per year (Handlemann, 2014). Experience curves and engineering assessments methods to analyse solar PV system cost reductions were used. Experience curves (or learning curves) is where, cost reductions are analysed as a function of market and production capacity expansion, and future cost reductions are estimated by projections of historical trends, bearing in mind the likelihood of historical drivers continuing into the future (Candelise et al., 2013). The main focus of the summary was mainly on recent cost and final end-customer price trends of PV modules over the last decade. The results were that both module and system costs and final end-customer price trends have reflected multiple overlapping forces. These were demand/supply dynamics, levels of market competition thus drivers which go beyond production costs themselves, production scale effects, industrial re-organisation and shakeouts, international trade policies and national market dynamics.

UK-DECC (2013) described the solar PV system deployment as significant due to reduction in component prices in recent years. The report also indicated the following: a progressive price reduction trajectory assumed in the period out to 2016 and 2020 that will reflect the advancements made in technology development and supply chains. Final end-customer price reduction is central to both small-scale and large-scale solar PV system deployment because prices for bill-payers are minimised. The key drivers are maximised opportunities in technology innovation; improved construction techniques and exploited supply chain competition; and the archived economies of scale. Oko et al. (2012) conducted a design and lifecycle cost analysis and simulation study of solar PV systems for the locality and specifically to develop one for the laboratory at the department of Mechanical Engineering, University of Port Harcourt in Nigeria. The unit final end-customer price of electricity for the designed solar PV system was high compared to the municipally supplied electricity. The final end-customer price of electricity was competitive with lowering final end-customer prices of solar PV system components and favourable government policies on renewable energy.

Enrst and Young (2011) also undertook an independent analysis of cost and deployment of a sample of ten developers, installers and manufacturers for a range of solar PV systems above 50kW, being installed commercially in the UK. The costs assessed were capital costs, operation and maintenance costs, life cycle costs and investor cost of capital. The Solar PV system sector had grown by 20% from 2000 to 2010. This growth was as a result of federal and state tax incentives. The 40% of capex costs were attributed to module cost reductions of 13-17% annually driven by reductions in silicon usage and efficiency of non-silicon based costs. The grid parity with final end-customer prices was expected to be achieved in the UK by 2020 without subsidy for non-domestic on- site installations. Similarly, Girona et al. (2006) observed that internationally solar PV system component final end-customer prices have decreased over the past decade. The reduction in the final end-customer prices was not only due to larger scale of production, advances in technology, innovation in manufacturing and recent declining prices of polysilicon but also increase in final end-customer prices of kerosene, gasoline and oil over the last decades (Ibid, 2006).

In summary, Girona et al. (2006); Enrst and Young (2011); Oko et al. (2012); Candelise et al. (2013); and UK-DECC (2013) have highlighted different parameters that have caused cost reductions in solar PV systems. These are demand and supply dynamics and levels of market competition; maximising opportunities in technology innovation; improving construction techniques and exploiting supply chain competition and the archiving economies of scale; increase in final end-customer prices of fossil fuels, favourable government policies on renewable energy; and federal and state tax incentives. This shows that cost reduction depends on different parameters depending on location of the solar PV system. It can be observed from the studies that although globally PV modules have declined, the solar PV system final end-customer price reduction depends on several factors like non-module costs, installation labour, local policies, increase in fossil fuels final end-customer prices and location of the system.

*2.4.2.3   Current solar PV system components final end-customer price drivers*
Goodrich et al. (2012) analysed solar PV system prices in the USA for residential and commercial rooftop systems and utility scale ground mount systems to determine the current price drivers and cost reduction opportunities. It was a highly-detailed and transparent bottom-up analysis to illustrate the installed solar PV system final end-customer prices in the second half of 2010. The results of the analysis were that the current final end-customer price drivers of

solar PV systems varied across market sectors primarily based on differences in system scale and installer channels to market. The final end-customer prices of solar PV systems in the USA and globally has dropped precipitously in recent years. The reasons were apparent disconnects between installation costs, component and system final end-customer prices, most notable is the impact of fair market value considerations on the system final end-customer prices.

Brazilian et al. (2013) reviewed a broad and recent range of academic, government and industry literature in order to highlight the key drivers and uncertainties of future solar PV system costs; final end-customer prices and potential; and established reasonable estimates for decision makers. There are three related metrics to analyse solar PV system costs (and final end-customer prices) namely: the price per Wp capital cost of PV module, the levelised cost of electricity (LCOE) and the concept of grid parity. It was found that the solar PV system industry has seen unprecedented declines in module final end-customer prices since the second half of 2008 yet many commentators, policy makers, energy user and even utilities around the world were not aware. Some of the reasons outlined were rapidity of cost and final end-customer price changes, the complexity of the solar PV system supply chain, BOS and installation costs, the choice of different distribution channels and differences between regional markets within which solar PV system is being deployed.

Goodrich et al. (2012) identified critical final end-customer price drivers of a solar PV system to include non-module costs, installation labour, regulatory costs site acquisition and preparation costs in the case of ground mount systems and module and non-module system efficiency. It was observed that although module final end-customer prices continue to fall, the contribution of non-module costs to the cost of solar energy increases. It was also observed that there was a critical relationship between module conversion efficiency and non-module area related costs and installation methods. The revolutionary improvements to module and non-module system components and installation methods are needed to accelerate solar PV system final end-customer price reduction. Candelise (2012) examined the significant reduction in solar PV system costs over time both at PV module and system level. The study discussed the major drivers behind PV module and system production cost and final end-customer price reductions using Solar buzz Retail Module Price Index. The key cost reduction drivers identified were increase in scale both in manufacturing capacity, market size and global dynamics as well as national learning.

UK-DECC (2013) sets out four guiding principles, which form the basis of government's strategy for solar PV system namely: delivering carbon reduction, energy security and affordable solar PV systems, understanding all carbon impacts of solar PV systems, proper sited solar PV system proposals and addressing challenges of deploying high volumes of solar PV systems. The principles would ensure future security of electricity supplies, drive the carbonisation of electricity generation and minimise costs to consumers. Kerstein et al. (2011) presented work aimed at consolidating historical final end-customer price and cost information, delivering refined curves for PV modules and systems and analysing the main factors of learning. The results were that module efficiency was an important factor on the learning rate because it led to savings along the whole value chain from the base material to the solar PV system. In another development, Tour, Glachart and Menie're (2013) predicted the cost of PV modules out to 2020 using experience curve models and drew implications about the cost of solar PV system electricity. It was observed that most combination of explanatory variables included both the experience measured by cumulative capacity with a one year lag and silicon price. The increase in cumulative capacity is responsible for 75% of this evolution and silicon price decrease is responsible for 25% of module price reduction.

In summary, Kerstein et al. (2011); Candelise (2012); Goodrich et al. (2012); and Tour et al. (2013) highlighted different current final end-customer price drivers of solar PV systems. These include both PV module and non-module costs, efficiency of solar PV systems, research and development, increase in scale both in manufacturing capacity, market size and global dynamics and national learning. It is difficult to understand these coherent shifts occurring across the solar PV system industry. In many cases current solar PV system final end-customer prices and associated market and technology shifts witnessed in the industry escape decision makers' awareness (Brazilian et al., 2013). The studies have illustrated different information regarding solar PV system components final end-customer price trends, causes of cost reduction and current price drivers.

### 2.4.3  Sources and logistics of solar PV system components
In sub-Section 2.4.2.1 studies have confirmed reduction in solar PV system final end-customer prices over the past decade. However, in developing countries, especially the sub-Saharan Africa, solar PV systems are still expensive because the products are fully imported and assembled from developed countries' markets (Girona et al., 2006).

Ondraczek (2011) noted that availability is one of the major drivers that need to be present to enable the widespread uptake of off-grid solar PV system in developing countries. For example, if PV modules were manufactured and assembled locally, it means existing markets can be developed, final end-customer prices reduced and eventually jobs and business created (Girona et al., 2006).

Ahlborg and Hammar (2012) explored barriers to renewable energy in Mozambique and Tanzania. They noted that one of the barriers to renewable energy is lack of rural markets or solar PV system components. In Mozambique, UEM (2010) also noted that availability of solar PV replacement components in terms of sources and logistics is one of the maintenance needs of off-grid solar PV systems. They appealed to institutions developing such projects to discuss and agree in detail before the project starts. In Malawi, most of the RET suppliers are based mainly in Blantyre and Lilongwe and a few in Zomba and Mzuzu (MERA, 2014). This indicates that people from the rural areas travel to the cities for their solar PV system needs. This situation is disadvantageous to the business models discussed in section 2.1.1 because income is reduced through transport costs. CES and MUREA (2014) recommended that sources and logistics of solar PV system replacement components should be such that people are able to purchase the components within the locality of the systems.

It can be concluded that sources and logistics of solar PV system replacement components contribute to failure of CSPV systems in developing countries. It is high time some of the components should be manufactured and assembled locally thereby reducing importation costs.

### 2.4.4   *Income Generating Activities*

Income Generating Activities (IGAs) are one of the crucial elements of CSPV systems economic sustainability. Mbaiwa (2004 p.206) described the relationship between modern energy and IGAs as follows: "an increase in IGAs can create demand for electricity, and vice versa". IGAs increase revenue for operation and maintenance of the systems in addition to members' contributions (Currie et al., 2012; and Ellegard et al., 2004). Schultz (2011) reported that at Bulembu Photovoltaic grid-tied System in Swaziland enterprises such as Bulembu Timber, Dairy, Honey, Bakery and Tourism proceeds contributed to the operation and maintenance cost of the CSPV system. Halder and Palvez (2015) agree that implementing solar PV systems with IGAs component is more acceptable in communities than those for lighting purposes only.

Currie et al., (2012) also reported about CSPV systems-owner business models and their IGAs in Malawi such as: Mikolongo Primary School CSPV system in Chikwawa where members pay MK50 for every mobile phone battery charging to get revenue for operating and maintaining the installed system. In addition, parents are requested to pay MK50 every month to increase the revenue. At Senga-Bay Baptist Medical clinic CSPV water pumping system, members do not pay for the water but make contributions after selling agricultural produce. The responsibility for short term costs of the scheme is in the members of the club, but long-term maintenance costs rest with the project. At Milonde Youth club Business Centre the CSPV system is used for charging mobile phone batteries, showing videos, barber shops and salons as a source of revenue to meet operation and maintenance costs. However, Mala, Schlaper and Tryor (2008) in their study to examine the role of solar PV systems on sustainable development in Kiribati, on the Pacific Islands observed that small-scale solar PV systems like SHS have a very little impact on IGAs for ordinary villagers. The study pointed out that SHSs are mainly useful for shop owners therefore should not be linked to IGAs because the technology may be inappropriate to communities whose objective is IGAs.

It can be summarised that IGAs, especially for system-owner business models, plays a very important role in enhancing CSPV systems economic sustainability in the long term. The only problem is the capacity of the CSPV system and the type of IGAs being undertaken.

### 2.5   Chapter summary:-

This chapter has reviewed CSPV systems in developed and developing countries. It has presented three different categories of CSPV system ownerships and these are system-owner, third-party and utility business models. The business models presented are both successful and unsuccessful. The literature review has also identified and analysed critical success factors from the CSPV system business models. In addition, it has presented how the different CSPV system business models are sustained economically. The major differences between CSPV systems in developed and developing countries have also been analysed. The literature has further reviewed the crucial elements of economic sustainability of CSPV systems namely solar PV system components standards and their final

end-customer prices trends, sources, logistics and IGAs. The following chapter will focus on research methodology. It will highlight research philosophy and approach, research design, data analysis, validity and reliability and ethical consideration employed in the study.

**Chapter 3:-    Research Methodology**
**3.0    Introduction:-**
This chapter outlines the research methodology utilised in the study. The chapter focuses on the research philosophy and approach; research strategy; target population; and sampling procedure; data collection and analysis; validity and reliability; and ethical consideration. Rajasekar, Philominathan and Chinnathambi (2013) described methodology as procedures by which researchers go about their work, explaining and predicting phenomena. The procedures are used to collect and analyse data for answering research questions and attaining the purpose of the research. Hancock et al. (2009) advocated that all research must use the most appropriate method or procedures to the research questions being asked.

**3.1    Research Philosophy and Approach:-**
This study is aligned to phenomenological research philosophy. Saunders, Lewis and Thornhill (2009) described research philosophy as the development of knowledge and the nature of that knowledge. The knowledge developed is not only attributed to new theory of human motivation but also in answering a specific problem in a particular organisation (Ibid, 2009). Philosophical orientations help clarify research designs and indicate the kind of evidence required, and data collection and interpretation (Chilipunde, 2010).

This study worked from an interpretivism epistemological paradigm and its associated methodology which guides social science research.  Greener (2008) highlighted that social science promotes the idea that subjective thought and ideas are valid. Epistemology is concerned with the researcher's view regarding what constitutes acceptable knowledge in a field of study. Bhattacherjee (2012) described epistemology as assumptions about the best way to study the world for example using an objective or subjective approach to study social reality. Interpretivism focuses upon details of situations, reality behind these details, subjective meanings and motivating actions (Saunders et al., 2009).

The interpretivism epistemology paradigm was relevant to this study because the researcher used own and participants' perceptions through physical inspection and unstructured interviews to investigate in depth CSPV system components specifications, replacement components final end-customer price trends, availability and IGA earnings. The paradigm helped this study to understand and interpret the subject of study based on the researcher's and participants' perceptions and experiences which can be verified (Hancock, Windridge and Ockleford (2009). The small samples also helped the study to collect detailed information as a fewer people are involved (Saunders et al., 2009). Further, this study employed an inductive approach because it did not have a theory from where to develop a hypothesis for testing but the concern was to collect, analyse and interpret data on CSPV system component specifications, replacement components final end-customer price trends, availability and IGA earnings.

**3.2    Research strategy:-**
This study used a qualitative exploratory mode of research. Qualitative research is considered appropriate if the research question is exploratory for example, exploring how people experience something or what their views are; and exploring a new area where issues are not yet understood or properly identified (Hancock et al., 2009).

Qualitative research uses predefined set of procedures to answer the research question and findings are not determined in advance (Mack et al., 2011). Qualitative research provides culturally specific and contextually rich data (Ibid 2011). Qualitative research is concerned with non-statistical methods and small purposively selected samples (Dawson, 2002). The advantages of qualitative research tradition are that open-ended questions to evoke responses are used and the researcher is allowed to probe initial participants' responses (Mack et al., 2011). Additionally, it seeks to understand a given research problem or topic from the perspectives of the local population it involves (Yin, 2011).

The objectives of this study were exploratory in nature therefore qualitative research tradition was the most suitable method to examine CSPV system components specifications, replacement components final end-customer price trends, availability and associated IGAs at Kuntiyani and Umodzi CBOs. Qualitative research tradition helped the study to get a deep understanding of what is going on at the two CBOs based on the participants' views. Open-ended

questions and probes to evoke participants' responses were also used. The qualitative research tradition also helped the study to use a purposively selected a small sample in order to get rich data with regard to the desired issues.

According to (Robson, 2002) as cited in (Saunders et al., 2009) an exploratory study is a valuable means of finding out what is happening, seeking new insights, asking questions and assessing phenomena in a new light. It is used to investigate the full nature of the phenomenon and other factors related to it. Cooper and Schindler (2011) highlighted that exploratory research is centered on loosely structured studies to gather further background information, expand understanding of the issue, and improve the research questions. Exploratory studies provide in-depth investigation of a particular process or phenomenon, and in this case, CSPV systems economic sustainability at Kuntiyani and Umodzi CBOs. Qualitative exploratory studies are also conducted when new and specific areas or topics are investigated (Broda, 2006).This study investigated this new area of interest of CSPV system fully instead of simply observing or describing the area.

Creswell (2009) defined strategies of inquiry as knowledge claims that provide specific direction for procedures in a research design. There are five strategies of inquiry associated with qualitative research tradition and these are ethnographies, grounded theory, case studies, phenomenological research and narrative research. This study utilised the case study research strategy of inquiry. A case study is used to describe a particular contemporary phenomenon within its real context using multiple sources of evidence (Saunders et al., 2009). Kombo and Tromp (2006) defined a case study as a unit which is described in detail, in context and holistically. Saunders et al. (2009) affirmed that the case study strategy is appropriate where you want to gain in-depth and rich data about a phenomenon. The case study strategy is also strong in discovering factors about a phenomenon that were not known in advance (Bhattacherjee, 2012). The weaknesses of the case study strategy include the following: It is difficult to generalise the findings of a single study to other situations (Saunders et al., 2009). There is possibility of biases in data collection because one person gathers and analyses the information (Ibid, 2009). Case studies are prone to errors therefore the researcher should have advanced researching skills (Ibid, 2009). In case studies internal validity of inferences is weak because there is no experimental control (Bhattacherjee, 2012).

The case study strategy of inquiry was appropriate for the study because it helped to obtain detailed information of the subject of the study with emphasis on the experiences of the researcher and the participants (Kombo and Tromp, 2006). It also helped to provide detailed information through inspections, questionnaire and focus group discussions (FGDs) in order to describe installed components specifications, their final end-customer price trends, availability and IGA earnings.

### 3.3    Target population and sampling procedure:-
*3.3.1    Target population*
The participants of this study were energy committee members, MERA, MBS and RET suppliers. The energy committee members were drawn from two CBOs pilot projects of Kuntiyani battery-based and water pumping CSPV system in Machinga and Umodzi battery-based CSPV system in Balaka. The CBOs were chosen firstly, to represent two different types of pilot CSPV systems that is water pumping and battery-based. Secondly, there is easy access of the study places in terms of proximity to tarmac roads as compared to the other pilot CSPV systems. Thirdly, Umodzi CBO has three institutions installed with CSPV systems at one place namely Mpiranjala CDSS, Mpiranjala Primary School and Namanja Health Centre. MERA was chosen to provide information about licensed RET suppliers and contractors in Malawi. MBS was chosen to provide information for MS solar battery-based and water pumping systems specifications. The RET supplier was chosen to provide information on final end-customer prices because of substantial experience in importation and selling renewable energy products. The RET supplier is also a licensed energy operator with MERA, a requirement for all energy operators in Malawi.

*3.3.2    Sampling procedure*
In this study sampling helped to save time and organise data collection efficiently and effectively for the study (Saunders et al., 2009).  Probability sampling is a method in which every unit in the population has a chance (non-zero probability) of being selected in the sample, and this chance can be accurately determined (Bhattacherjee, 2012). Non-probability sampling is a sampling method in which some units of the population have zero chance of being selected or where the probability of selection cannot be accurately determined (Ibid, 2012).

This study was about examining installed CSPV systems essential component specifications, final end-customer price trends, availability and associated IGAs for purposes of illustration or explanation, hence, a non-probability sampling method was considered to be the most suitable. Non-probability sampling was used to choose a small

sample through a deliberate process to represent the desired population and participants were selected based on their first-hand experience of the phenomena of interest (Ritchie and Lewis, 2003). The type of non-probability sampling method used in the study was purposive or judgmental sampling. Purposive sampling enables this study to use own judgment to select cases that will best answer research question(s) and meet objectives (Saunders et al., 2009). In this study Umodzi and Kuntiyani CBO's energy committee members, MERA, MBS and RET suppliers were purposefully chosen to respond to the research questions.

### 3.3.3   Sample size
A sample is the actual units selected for observation (Bhattacherjee, 2012). Kothari (2004) highlighted that if a study is for exploratory purposes, no attempt is made to examine a random sample of a population but rather individuals who are knowledgeable about a topic or process. Saunders et al. (2009) also highlighted that the issue of sample size in non-probability sampling is unclear and there are no rules. The sample size for this study depended on participants that were familiar and knowledgeable about the CSPV systems. This study intended to have a sample of at least 10 members from each CBO energy committee. However, this was only achieved at Kuntiyani CBO where twelve (12) participants were present. The 12 participants composed of 2 CBO members, 2 village development committee members, 2 SMC members, 2 PTA representatives, 2 teachers and 2 students. At Umodzi CBO the sample was made up of six (6) participants. The other members were informed but were not present because of undisclosed reasons. The 6 participants were composed of energy committee members and PTA representative. This study intended to have 50:50 gender balance but this was only achieved at Umodzi CBO. At Kuntiyani CBO the sample was made up 8 men, 4 women. At Umodzi CBO there were 3 men and 3 women.  Other samples were MERA and MBS. Similarly, this study intended to have at least a sample of 2 RET suppliers, one in Blantyre and the other one in Lilongwe. However, only one RET supplier from Lilongwe responded after several reminders.

### 3.4   Data Collection:-
This study used both primary and secondary data. The data collection was conducted between September, 2015 and February, 2016.

### 3.4.1   Primary data
Primary data for this study consists of information obtained from physical inspections of the installed CSPV systems, questionnaire by RET supplier and FGDs conducted with CBOs energy committees. These people played different roles towards the installation of the CSPV systems.

### 3.4.1.1   Physical inspection
To assess the compliance of individual system components with MBS specifications, data was collected by physical inspection of the installed CSPV system components of Umodzi and Kuntiyani CBOs. Physical inspection on the name plate of the component, data sheets obtained through the internet were also used to check compliance of the components. In the development of a solar PV system common mistakes occur in a number of stages and these are site selection, design and planning of the system, physical installation of components, safety and service (inspection and maintenance). Therefore, in addition to checking compliance of the essential CSPV system components with MBS specifications, site selection, physical installation, safety and service were also checked. The physical inspection did not go further to test the individual components against electrical and mechanical failures which both falls under the design and planning stage. Electrical and mechanical failures tests could have checked if the installed component name plate's data were truthful because MERA and MBS have inadequate capacity to check every component.

Inspection sheets to guide the physical inspection and for verifying compliance with the MBS specifications were prepared and are attached in Appendix B. The essential components of the CSPV systems inspected were PV modules, inverter, batteries and charge controller, submersible pump, pump controller and water storage tank. Data was collected from data sheets and name plates of the components. The data collected for CSPV system components were general information, technical information, labels, circuit protection, lifespan and warranty period.

### 3.4.1.2   Questionnaire
To establish replacement component final end-customer price trends, data was obtained from a RET supplier using a questionnaire. This study planned to collect component final end-customer prices from at least two RET suppliers from Blantyre and Lilongwe. The reason was to compare final end-customer prices of similar components from two different RET suppliers. Questionnaires were sent to over 10 RET suppliers obtained from MERA list of Licensed

Energy Operators for 2014. After two weeks reminders were sent through email and telephone but only one RET supplier responded. This study went ahead to use the data because the RET contractors indicated that they purchased some of the components from the RET supplier who responded to the questionnaire. In addition, the RET supplier is reputable and long standing in the solar PV system importation and selling. The questionnaire design had closed-ended questions as shown in Appendix C.

The questionnaire was sent to two RET suppliers initially, to obtain comments on the questionnaire items and determine the time it takes to complete the document. The results indicated that there were no problems with regard to understanding or answering questions and all instructions were correctly followed. The pilot study took 30 minutes to complete the questionnaire.

### 3.4.1.3   Focus group discussions

To establish components sources and associated logistics and IGA earnings, data were collected using focus group discussions (FGDs). This study conducted two FGDs, one with Umodzi CBO and the other one with Kuntiyani CBO (FGDs interview Guide is presented in Appendix D). The FGDs at Umodzi was made up of six (6) participants while that at Kuntiyani was made up of twelve (12) participants. The difference came about because at Umodzi CBO some energy committee members did not turn up due to unknown reasons. Each session of the FGDs took about three hours. The FGDs were audio-recorded in addition to note taking in order to obtain adequate data. The collected data were transcribed into a Microsoft Word transcript as shown in Appendix E.

### 3.4.2   Secondary data

Malawi Standards for battery-based and water pumping solar PV system specifications obtained from MBS were reviewed and compared with data obtained from physical inspection of the CSPV systems. IGA account records were also obtained from Umodzi and Kuntiyani CBOs energy committees.

## 3.5   Data analysis, interpretation and presentation:-

The study used both qualitative and quantitative data analysis techniques to analyse the collected data. The data collected through physical inspections of the installed CSPV systems were analysed using comparative analysis. The data collected was compared with Malawi Standards for battery-based and water pumping solar PV systems specifications; and variation between the data was described (see Section 4.1).

The data collected through physical inspections of the installed CSPV systems were analysed using comparative analysis. The similarities and differences between the data collected through physical inspections and Malawi Standards for battery-based and water pumping solar PV systems specifications were examined. A narrative report of similarities and differences between the data was written (see Section 4.1).

The data collected to show CSPV system replacement essential components final end-customer prices and trends were entered into the computer and checked for errors and exploratory data analysis approach (EDA) was identified as the most appropriate.  EDA involves the use of diagrams to present, interpret and analyse data (Saunders et al., 2009). SPSS was used to generate bar charts and line graph to show CSPV system replacement essential components final end-customer prices and trends respectively. The generated graphs were interpreted and analysed by discussing the relationship between the components final end-customer prices, trends and incentive proportions (see Section 4.2).

The data obtained from FGDs were transcribed into Microsoft word document and analysed using content analysis. The data was coded, described and interpreted depending on the predetermined themes identified to respond to the research questions. The themes were demographic information, background information, availability of CSPV system components, income generating activities and opinion. Direct quotations were also used to present the findings (Kombo and Tromp, 2006).

The IGA account records obtained from the energy committee treasurers were entered into the computer, explored and analysed. SPSS was used to generate the data. Frequency analysis was used to study the respondents' characteristics such as age, gender, length of service and personal involvement. A Bar graph was used to present the IGA earnings (Section 4.3). Further analysis included calculation of Net Present Values (NPVs) to appraise the CSPV systems economically (Appendix H - Tables H3 and H4).

**3.6   Validity and Reliability:-**
Saunders et al. (2009) indicated that validity is the extent to which data collection methods accurately measure what they were intended to measure. In qualitative studies validity is high but reliability is low. The following were done to ensure validity of the study findings was attained:

(a)   Two sessions of FGDs, one at each CBO.
(b)   The questionnaire was also pilot tested before sending it to the purposively chosen RET supplier.

Reliability is the extent to which data collection techniques will yield consistent findings, similar observations would be made or conclusions reached by other researchers or there is transparency in how sense was made from the raw data (Saunders et al., 2009).  An adequate sample from two different CSPV systems pilot projects were used although purposively sampled to ensure a degree of reliability of the findings.

**3.7   Ethical Consideration:-**
Research ethics is the appropriateness of the researcher's behaviour in relation to the rights of those who become the subject of work or those that are affected by it (Saunders et al., 2009). The ethical considerations that were taken into account in this study included informed consent, confidentiality, anonymity, integrity and privacy.

A letter was obtained from University of Malawi, The Polytechnic asking for permission to conduct the study (see Appendix G). From this, participants were also notified of the type of study to be carried out. Participants were further informed to be as accurate and honest as possible in their responses. A consent form was attached to the interview guide for FGDs which participants signed before commencement of the interview. The purpose of the study was explained clearly without distortions and participants were given the opportunity to ask questions. The participants understood the requirements of the study and voluntarily decided to take part in the study. Participants were also protected from any harm and informed that they had the right to withdraw from participation at any time.

Participants were informed that the results of the study were strictly confidential. For example, audio recording would be used during the interviews but for purposes of confidentiality the transcribed data would be destroyed after completing the study. Participants were also not asked to provide their personal or trade names. It can be noted from the FGDs interview questions and questionnaire that the respondents have not been asked to indicate their names anywhere on the documents. This is a clear indication of confidentiality and anonymity. Respondents were only required to indicate their age, years of experience in the field and their gender.

**3.8   Chapter summary:-**
This chapter has discussed the research philosophy and approach; research design; data analysis; validity and reliability and ethical consideration that were utilised in assessing CSPV system essential component specifications, final end-customer price trends, sources, logistics and IGA earnings to ensure economic sustainability of Kuntiyani and Umodzi CSPV systems. The next chapter presents results and discussion of the collected data in the study.

**Chapter 4:- Results and Discussion**
**4.0   Introduction:-**
This chapter presents and discusses the findings of examining CSPV system essential component specifications, final-end customer price trends, availability and associated IGAs to ensure economic sustainability. The data was analysed by using both quantitative and qualitative techniques. The results are based on Kuntiyani and Umodzi CBOs CSPV systems in Balaka and Machinga districts respectively.

**4.1   Compliance of the installed CSPV system essential components with Malawi Bureau of Standards specifications:-**
The study adopted the MS battery-based and water pumping solar PV system specifications presented in Appendix A - Table A1 and Table A2 respectively to physically inspect the installed CSPV system components. The specifications inspected were general and technical characteristics, labels, circuit protection, lifespan and warranty period for the major components.

*4.1.1   General characteristics of the installed CSPV system essential components*
Table 4.1 indicates the general characteristics of the essential CSPV system components installed at Kuntiyani and Umodzi CBOs. The table shows that the installed PV modules are replaceable identical mono-crystalline type with

sealable water proof International Protection (IP) 54 junction and aluminium frame box. The monocrystalline PV module has the highest conversion efficiency amongst PV cell technologies about 12.5-15%, (Tan and Seng, 2009). The batteries are the deep cycle sealed (Valve regulated) type. The charge controllers are the type with overcharge and discharge protection and has indication status (charging status, battery status (Low voltage (LV) and Low Voltage Disconnect (LVD) (see figure 4.1). The water pump is self-priming and self- lubricating and made of corrosion resistant, weather resistant and water tight materials with sound pressure of less than 70 decibels (dB). The pump controller is weather resistant and water tight with indicators for system status and its terminals/ leads are clearly marked for the power supply, water pump, earth leakage and tank water level.

**Table 4.1:-** General characteristics of the installed cspv system essential components

| Component | Characteristics | Status | Description | Remarks |
|---|---|---|---|---|
| PV modules | Single- Crystalline or poly-crystalline, 36 series type | Yes | Mono-crystalline | Complied |
| | Sealable water proof IP54 Junction box with diode | Yes | - | Complied |
| | Framed with an aluminium frame | Yes | - | Complied |
| | Replaceable identical PV modules | Yes | - | Complied |
| Batteries | Deep cycle vented or sealed (Valve regulated) | Yes | Deep cycle sealed | Complied |
| Charge controller | Charging, control (overcharge and discharge protection) | Yes | - | Complied |
| | Indication status (charging status, battery status (LV, LVD) | Yes | - | Complied |
| Water pump | Self-priming and self- lubricating | Yes | - | Complied |
| | Corrosion resistant materials | Yes | - | Complied |
| | Weather resistant and water tight controller | Yes | - | Complied |
| | Sound pressure of less than 70 DB | Yes | - | Complied |
| Pump controller | Indicator system status | Yes | - | Complied |
| | Weather resistant and water tight | Yes | - | Complied |
| | Clearly marked terminals | Yes | - | Complied |
| Storage tank | Durable, non-corrosive materials, withstand pressures and wind loads when mounted and fully filled up and tank capacity marked. | Yes | | Complied |



**Figure 4.1:-** Charge and pump controllers' indication status for charging water pumping status at Umodzi and Kuntiyani CBOs

*4.1.2   Technical characteristics of the installed CSPV system essential components*

Table 4.2 indicates the technical characteristics of the installed CSPV system essential components. The power ratings for the PV modules are 80W and 100W, current rating of 4.5A - 5.5A and output voltage of 12 volts (V) direct current (DC). The battery sizes are 96Ah, 12VDC with 30% depth of discharge, charge control and lugged terminals. The inverter converts 12V-DC to 240V alternating current (AC) at a frequency of 50 Hertz (Hz). The charge controllers have set point voltages and current rating of 12V / 24V and 20A or 30A. The water pump power was rated at 0.51kW and 0.63 cubic metres per second ($m^3$/s).  The pump controller was rated 5W and 30A /30-300VDC.

**Table 4.2:-** Technical characteristics of the installed CSPV system essential Components

| Component | Characteristics | Status | Description | Remarks |
|---|---|---|---|---|
| PV modules | Rating (power, current, voltage) | Yes | 80W and 100W, 4.5A -5.5A, 12VDC | Complied |
| Batteries | Rating | Yes | 96Ah (C/20 discharge rate | Complied |
| | Cycle life at several depths of discharge | Yes | 30% depth of discharge | Complied |
| | Voltage | Yes | 12VDC | Complied |
| | Terminals lugged (bolt-nut) | Yes | - | Complied |
| | Charging control (overcharge and discharge protection) | Yes | - | Complied |
| Inverter | DC-AC inverter 240VAC+/-10% 50Hz output | Yes | - | Complied |
| | Output voltage | Yes | 240VAC sine wave, efficiency of 85% at above 50% load output | Complied |
| Charge controller | Set point voltage | Yes | 12V/24V | Complied |
| | Current rating | Yes | 20A or 30A | Complied |
| Water pump | Rating | Yes | 0.51kW | Complied |
| | Pumping rate | Yes | - | Complied |
| Pump controller | Current /voltage | Yes | 30A/30-300VDC | Complied |
| | Rating | Yes | 5W | Complied |

*4.1.3   Label of the installed CSPV system essential components*

It is very important that solar PV components have a label where information such as manufacturer's details and ratings are indicated because labelling ensures safety on stand-alone power systems therefore it should be correct and clear (Brazier, 2009).  BRE et al. (2006) indicated that labeling must remain clear, visible and affixed through the lifetime of the system. This study found that all the installed CSPV system essential components had manufacturer's details label as indicated in Table 4.3.

**Table 4.3:-**    Label of the installed CSPV system essential components

| Component | Specification | Status | Description | Remarks |
|---|---|---|---|---|
| PV modules | Manufacturer's details | Yes | Suntech STP 080/085/100 | Complied |
| Batteries | Manufacturer's details | Yes | Raylite Deep cycle (Maintenance free) | Complied |
| Inverter | Manufacturer's details | Yes | Eurostar (Pure sine wave) | Complied |
| Charge controller | Manufacturer's details | Yes | Steca | Complied |

| | | | Maximum power point tracker (MPPT) | |
|---|---|---|---|---|
| Water pump | Manufacturer's details | Yes | Grundfos SQ flex 2.5-2 solar submersible pump | Complied |
| Pump controller | Manufacturer's details | Yes | Grundfos CU 200 SQFlex control unit | Complied |

PV modules are from Suntec. Batteries are deep cycle (maintenance free) manufactured by Raylite. Inverters are a pure sine wave type from Eurostar manufacturers. Charge controllers are manufactured by Steca and have a MPPT. Water pump and pump controller are Grundfos models.

### 4.1.4 *Circuit protection of the installed CSPV system essential components*
The MS battery-based solar PV systems indicate that solar PV system components such as inverter, charge controller, water pump and pump controller should have circuit protection facilities. Circuit protection allows for maximum protection and safety on components in addition to build in protection (MS 695, 2004). Table 4.4 indicates that the installed inverters have reverse polarity and short circuit protection. Charge controllers had short circuit, reverse polarity, reverse leakage current and surge protection. Water pump had dry running, over / under voltage, overload and over- temperature protection. Pump controller had short circuit, reverse polarity and overload protection.

**Table 4.4:-** Circuit protection of the installed CSPV system essential Components

| Component | Specifications | Status | Description | Remark |
|---|---|---|---|---|
| Inverter | Circuit protection | Yes | Reverse polarity and short circuit | Complied |
| Charge controller | Circuit protection | Yes | short circuit, reverse polarity, reverse leakage current and surge protection | Complied |
| Water pump | Circuit protection | Yes | Dry running, over /under voltage, overload and over temperature protection | Complied |
| Pump controller | Circuit protection | Yes | Short circuit, reverse Polarity and overload protection | Complied |

### 4.1.5 *Lifespan of the installed CSPV system essential components*
Lifespan is the natural life of a product (Gevorkian, 2008). The lifespan of products depends on how it is being taken care of (Ibid, 2008). It is important that the life expectancy of solar PV system components are known to enable planning for replacement (Ibid, 2008). Table 4.5 indicates that the installed PV modules can stay on the roof tops between 20-25 years. The installed battery lifespans were rated at 5 years, inverters at 10 years, charge controllers at 15 years and that of water pumps and pump controllers at 15 years each. Gevorkian (2008) cautioned that if products are not properly used and maintained their lifespan is reduced. For example, battery lifespan depends on depth of discharge and the recommended depth of discharge each time is 30% to 40% (Ibid, 2008).

**Table 4.5:-** Lifespan of the installed CSPV system essential components

| Component | Specifications | Status | Description | Remarks |
|---|---|---|---|---|
| PV module | Minimum lifespan | Yes | 20 - 25 years | Complied |
| Batteries | Minimum lifespan | Yes | 5 years | Complied |
| Inverter | Minimum lifespan | Yes | 5 years | Complied |
| Charge controller | Minimum lifespan | Yes | 15 years | Complied |
| Water pump | Minimum lifespan | Yes | 10 years | Complied |
| Pump controller | Minimum lifespan | Yes | 10 years | Complied |

### 4.1.6 *Warranty period of the installed CSPV system essential components*
Manufacturer's assurance that a product will perform satisfactorily is an important aspect in marketing (Podolyakina, 2016). Warranty period is the duration a manufacturer assures a customer that should a product

malfunction within that period, it can be repaired for free or exchanged (Ibid, 2003). Table 4.6 indicates the minimum warranty period of the installed CSPV system components. In Malawi, (BIF, 2014) found out that businesses do not offer warranties because of the following reasons: it reduces profit margins; customers often do not say the truth; customers use products carelessly; and warranties are not offered way back from manufacturers of RET products. The installed PV modules had a shorter warranty period of 5 years instead of 10 years, batteries, inverter and water pump -1 year each and pump controller - 2 years as indicated in the Table 4.6. There was evidence that the RET contractors would comply with the stated warranties because they left handover notes at both CBOs. Another proof of evidence is that when an inverter was burnt at Umodzi CBO before its warranty period of 1 year expired, only labour, transport and subsistence allowances were paid to the contractor.

**Table 4.6:-** Warranty period of the installed CSPV system essential components

| Component | Specifications | Status | Description | Remarks |
|---|---|---|---|---|
| PV module | Minimum warranty period (MWP) | No | 5 years | 10 years |
| Batteries | MWP | Yes | 1 year | Complied |
| Inverter | MWP | Yes | 1 year | Complied |
| Charge controller | MWP | Yes | 2 years | Complied |
| Water pump | MWP | Yes | 1 year | Complied |
| Pump controller | MWP | Yes | 2 years | Complied |

Tables 4.1 to 4.6 illustrate that all the essential components installed at the two CBOs complied with the MS for battery-based and water pumping system specifications. In addition the CSPV systems were checked against common mistakes that occur during solar PV system implementation namely site selection, design and planning of the system, physical installation of components, safety and service as indicated in Table 4.7. The results are contradicting with (Youngren, 2011) who indicated that in most sub-Saharan African countries, poor solar PV system components and materials are used. In the case of the two CBOs, by complying with Malawi Bureau of Standards specifications, it means that proper components were installed on the systems. Thus, the results indicate that proper components were installed at Kuntiyani and Umodzi CBOs CSPV systems. The contributing factor to proper components is that MERA certified companies were engaged to design and install the systems. These legally certified companies provide quality assurance to customers, assurance of after sales services and records keeping for installed systems which can be tracked in case of theft (CES and MUREA, 2012). This is in agreement with Konkle (2014) who argued that CSPV systems should be designed, installed, operated and maintained by professionals to achieve sustainability.

**Table 4.7:-** Site selection, design and planning of the system, physical installation and safety

| Item | Description | Remarks | |
|---|---|---|---|
| | | **Kuntiyani CBO** | **Umodzi CBO** |
| **Site inspection** | | | |
| 1. | PV modules orientation | Facing towards the north | Facing towards the north |
| 2. | PV modules angle of inclination from the horizontal | 30$^o$ | 30$^o$ |
| 3. | Shading of PV modules | Not shaded | Not shaded |
| 4. | Condition of roof | Good | Good |
| **Physical installation** | | | |
| 1. | Tight or loose cables | Tight | Tight |
| 2. | Connections | Good | Good |
| 3. | Ventilations | Good | Good |
| 4. | Earth protection | Provided | Provided |
| **Safety** | | | |
| 1 | Improper polarity | No | No |
| 2. | Obstruction against fire | No | No |
| **Service** | | | |
| 1. | Manual, warranties, test certificates if provided to the owner | Yes | Yes |

It can be summarised that the essential components installed at Kuntiyani and Umodzi CBOs complied with most of the MBS specifications for battery-based and water pumping systems. Common mistakes that occur at different stages of developing a solar PV system were reduced. The next section presents and discusses CSPV system essential replacement components final end-customer price trends.

**4.2   CSPV system essential replacement components final end-customer price trends:-**

*4.2.1   Characteristics of the RET supplier*

An experienced and reputable RET supplier responded to the questionnaire to establish essential replacement component final end-customer prices trends. The characteristics of the RET supplier were important to ensure credibility of the feedback. The data collected were the number of years the RET supplier has been in business, location, nature of business and the products that the RET supplier imports or sells. Table 4.8 indicates that the RET supplier is based in Lilongwe city in Malawi and has been in the business of selling and importing RET products for more than 15 years. The supplier is both a wholesaler and retailer and the products that are imported and sold include solar panels, batteries, inverters, charge controllers, solar water pumps and pump controllers.

**Table 4.8:-** Characteristics of the RET supplier

| Item | Question | Response |
|------|----------|----------|
| 1 | Period in the business | More than 15 years |
| 2 | Location | Lilongwe |
| 3 | Nature of business | Wholesaler and retailer |
| 4 | Solar PV system imported and sold | Solar panels, batteries, inverters, charge controller, solar water pump and pump controller |

*4.2.2    CSPV systems essential replacement components final end-customer prices in May, 2014*

Figure 4.2 displays the final end-customer prices of the installed CSPV system essential replacement components in May, 2014. Final end-customer prices of PV modules and charge controller are average prices while for the other components are absolute (see Appendix F - Table F1). The graph was generated using final end-customer prices for 80W and 100W PV modules, 96Ah batteries, 20A and 30A charge controller, 600VA inverter, 0.51kW water pump and 5W pump controller. The prices considered were retail prices. The graph also indicates that the component final end-customer prices for battery-based solar PV system were lower than that of the water pumping system. This means that solar water pumping system is a bigger investment than battery-based solar PV system.
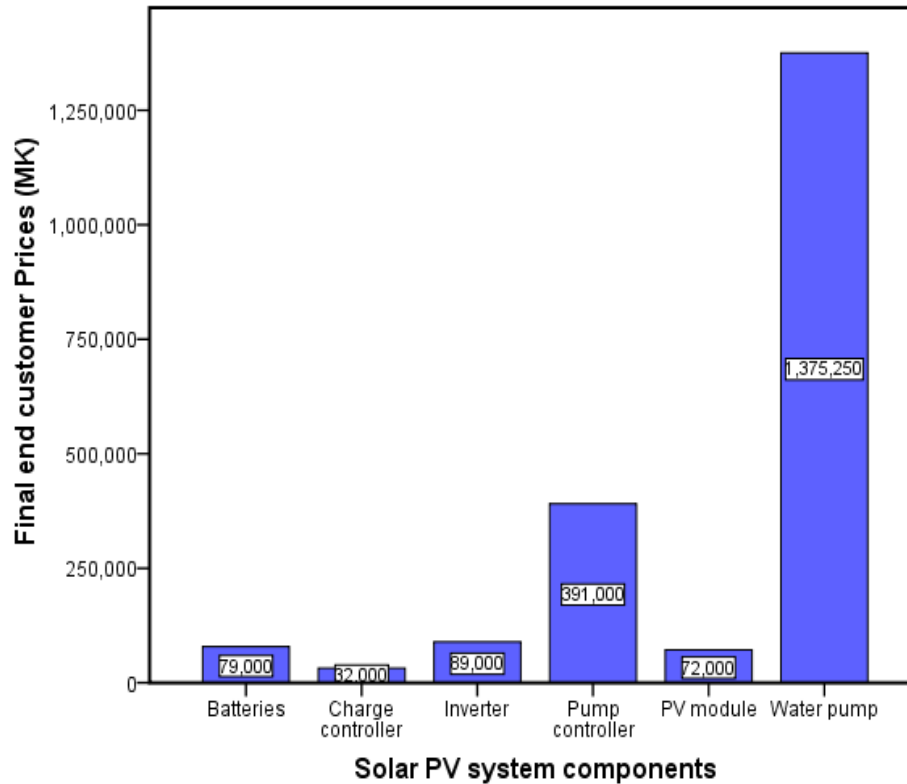
**Figure 4.2:-** CSPV systems essential replacement components final end-customer prices in May, 2014

*4.2.3        Incentive proportions in the essential replacement components final end-customer prices*
Figure 4.3 displays the proportions of incentives in the solar PV system essential replacement component final end-customer prices in Malawi. The final end-customer prices of solar PV system components have proportions of 100% free on board, 30% cost of insurance and freight (CIF), 30% licensees mark-up except for the water pump which has 50% and 20% other costs. On the duty waiver on solar PV system components the respondent argued that:

"GoM has removed duties on solar unilaterally but this has resulted negatively as a lot of sub-standard goods also come in duty free thus cheating customers as well as government losing revenue. Duty waiver needs to be controlled as before".
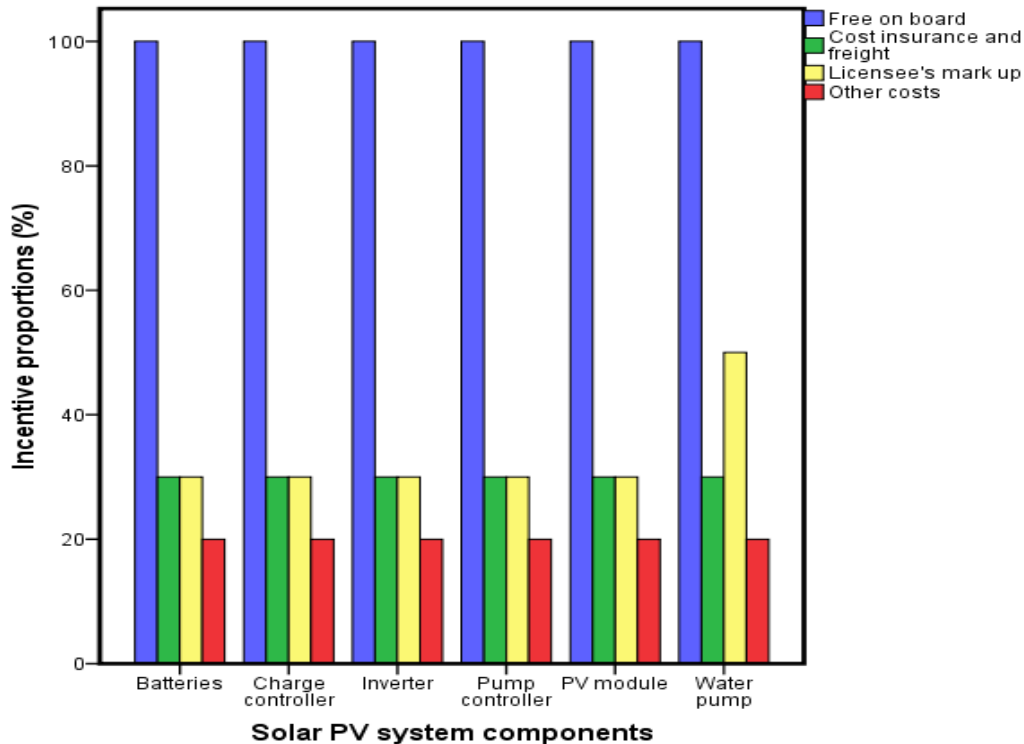
**Figure 4.3:-** Incentive proportions for CSPV systems essential replacement component final end-customer prices in Malawi

*4.2.4   CSPV systems essential replacement component final end-customer price trends in Malawi for 2014-2015*
Figure 4.4 displays essential replacement component final end-customer price trends in Malawi for 2014-2015 for the installed CSPV systems namely, PV module, battery charge controller, inverter, water pump and pump controller. It was important to first of all display the replacement component final end-customer prices and incentives (Figures 4.2 and 4.3) to facilitate understanding of the final end-customer price trends. The graph was generated using replacement component final end-customer prices for 80W and 100W PV modules, 96Ah batteries, 20A and 30A charge controller, 600VA inverter, 0.51kW water pump and 5W pump controller from May 2014 to December, 2015 (Appendix F - Table F2). The graph indicates the replacement components final end-customer prices between 2014 and 2015 exclusive of transport and maintenance costs. The trends show that the replacement component final end-customer prices were increasing moderately. The results are different from Feldman et al. (2012); Krautmann and Zhu (2012); Reichelstein and Yorston (2012); Barbose et al. (2013); and Brazilian et al. (2013);  who indicated that globally, solar PV system final end-customer prices have declined in recent years.  The reasons for the decline in solar PV system final end-customer prices were reduction in PV module and non-module costs, installation labour, local policies, increase in fossil fuels final end-customer prices and location where the solar PV system is installed.
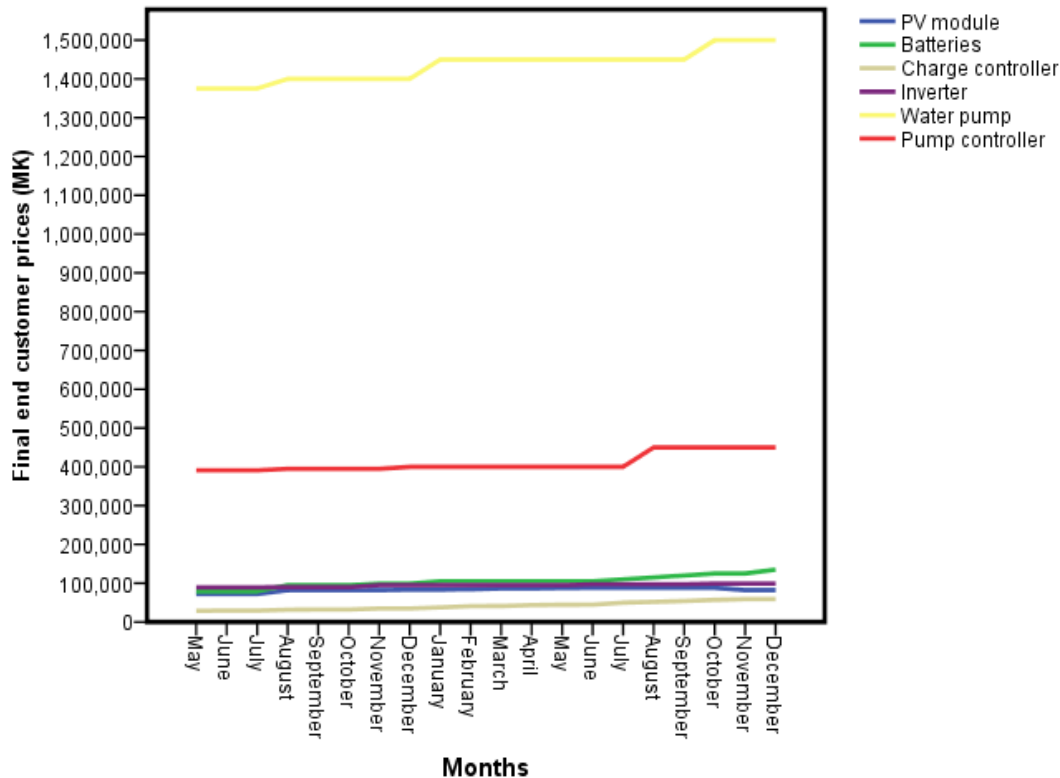
**Figure 4.4:-** CSPV systems essential replacement component final end-customer price trends in Malawi between 2014 and 2015

However, Malawi is one of the developing countries in sub-Saharan Africa where all solar PV system components are imported, as a result, the final end-customer prices have to include importation costs (Girona, 2006). For example, Figure 4.2 illustrates 30% CIF which is added to the essential replacement component final end-customer prices shown in Figure 4.3. The results are in line with the study by Girona et al. (2006) who indicated that in developing countries especially the sub-Saharan, solar PV systems are still expensive because the products are imported and assembled from overseas markets. The results indicate moderate increasing trends across 2014 / 2015 period as illustrated in Figure 4.4 despite the decline experienced in some developed countries in recent years as reported by (Feldman et al., 2012; Krautmann and Zhu, 2012; Reichelstein and Yorston, 2012; Barbose et al., 2013 and Brazilian et al., 2013) in the literature review. This is as such because of the duty free status government policy on all solar PV system as indicated in the literature review otherwise the increase would have been enormous. The results confirm with Barbose et al. (2013) who indicated that government incentives encourage rapid growth of solar PV systems and replacement component final end-customer price reductions over time. This is in contrary with the RET supplier who responded to the questionnaire and criticised the government of Malawi that incentives like the duty free status is contributing to government loss of revenue and inflow of sub-standard components. The results also indicate that the moderate increasing trends in the essential replacement component final end-customer price trends could be as a result of the CIF and inflation rate. The next section presents CSPV systems essential replacement component sources, logistics and IGA earnings.

**4.3   CSPV systems essential replacement component sources, logistics and IGA earnings:-**

*4.3.1   Participants' characteristics*

The participants' characteristics collected were gender, age, work experience and highest qualification of participants as illustrated in Table 4.9.

*4.3.1.1   Gender*

Table 4.9 indicates that there were a total of 12 participants at Kuntiyani CBO FGDs of which 8(60%) were male and 4(40%) were female. At Umodzi CBO a total of 6 people participated in the study of which 3(50%) were male

and 3(50%) were female. Participants at Kuntiyani CBO were predominantly males while at Umodzi CBO there was equal representation of males and females. It was noted that women in the communities are taking part in energy issues although Kuntiyani CBO participants were predominantly male. The age of participants is also considered as a vital aspect and will be discussed next.

**Table 4.9:-**   Participants' characteristics at Kuntiyani and Umodzi CBOs

| Characteristics | Category | Frequency | Valid percent | Frequency | Valid percent |
|---|---|---|---|---|---|
| | | **Kuntiyani N=12** | | **Umodzi N=6** | |
| Gender | Male | 8 | 60 | 3 | 50 |
| composition | Female | 4 | 40 | 3 | 50 |
| Participants | 20 - 30 years | 3 | 25 | 1 | 16.7 |
| Age | 31 - 40 years | 5 | 40 | 3 | 50 |
| | 41 - 50 years | 3 | 25 | 1 | 16.7 |
| | 50+ years | 1 | 10 | 1 | 16.7 |
| Experience of | 0 - 5 years | 12 | 100 | 6 | 100 |
| Highest | Below Standard 8 | 1 | 10 | - | - |
| qualification | Standard 8 | 3 | 30 | 3 | 50 |
| | JCE | 2 | 15 | 1 | 16.7 |
| | MSCE | 2 | 15 | 1 | 16.7 |
| | Professional Certificate | 2 | 15 | - | - |
| | Diploma | 2 | 15 | 1 | 16.7 |

### 4.3.1.2   Age of participants
In this study age was considered as an essential aspect of reliability of the research findings (Table 4.9). Between 20-30 years there were 3(25%) participants at Kuntiyani CBO and 1(15%) participant at Umodzi CBO. Between 31-40 years CBO there were 5(40%) at Kuntiyani and 3(40%) at Umodzi CBO. Between 41-50 years there were 3(25%) participants at Kuntiyani CBO and 2(30%) at Umodzi CBO. At 50 years and above there was 1(10%) at Kuntiyani CBO and 1(15%) at Umodzi CBO. The majority of participants at both Kuntiyani and Umodzi CBO were within the age of 31-40 years. There were fewer participants aged 50 years and above. This indicates that the participants were mature enough to participate in the FGDs.

### 4.3.1.3   Participants experience
Participants experience in community energy committees was also considered as another essential aspect of reliability of the research findings (see Table 4.9). Chilipunde (2010) highlighted that in-depth knowledge is vital for any business that one undertakes. In this study all the participants fell in the category 0-5 years of experience in community energy. This is a reflection of when the CSPV systems were introduced. Despite the low experience, their responses were trustworthy.

### 4.3.1.4   Highest qualifications
The highest qualification of participants was considered as one aspect of reliability of the research findings (see Table 4.9). Finally, participants' highest qualifications were as follows: Below standard 8 there was 1(10%) of participants at Kuntiyani CBO. Three (30%) of the participants had standard 8 qualifications at Kuntiyani CBO and three (40%) of participants at Umodzi CBO. Two (15%) of the participants had Junior Certificate of Education (JCE) at Kuntiyani and one (16.7%) at Umodzi CBO. Two (15%) of the participants had Malawi School Certificate of Education (MSCE) and 1(16.66%) participant at Umodzi CBO. Two (15%) of the participants had a Certificate in teaching and two (15%) of the participants had Diplomas at Kuntiyani CBO while at Umodzi only one participant had a Diploma. The results indicated that most participants had attained basic academic education at both CBOs. This means that the participants had the ability to understand and discuss the FGDs questions, understand RETs and could easily be trained on how to manage income generating activities earnings to ensure economic sustainability of the CSPV systems.

*4.3.2   Sources and logistics of CSPV system essential replacement components*

In Malawi travelling to rural areas is difficult because 74% of road network is unpaved as such deteriorate very fast especially during the rainy season (Mtawali, 2010). This study noted that the CSPV systems were installed in the remotest areas with difficult accessibility due to poor road conditions. Therefore, it was important to investigate the sources and logistics of essential replacement components for the installed CSPV systems at Kuntiyani and Umodzi CBOs. The sources of essential replacement solar PV system components and means of transport and cost are presented and discussed.

It is important to establish where essential replacement components for the installed CSPV systems are purchased for the CBOs to maintain the systems. This study noted that the main sources of essential replacement components for the installed CSPV systems were Blantyre city (177 kilometres (km) and 170km from Kuntiyani and Umodzi CBOs respectively), Lilongwe city (251km and 286km from Kuntiyani and Umodzi CBOs respectively) and Zomba city (135km and 106km from Kuntiyani and Umodzi CBOs respectively (MERA, 2014). Participants at Umodzi CBO indicated that the nearest places where the essential replacement components for the installed CSPV system can be purchased are Blantyre and Zomba cities but most of the components were purchased from Lilongwe city. Similarly, participants at Kuntiyani CBO said that essential replacement components were purchased from Balaka district and Lilongwe city. This confirms literature review where Ondriczek (2011); and Ahlborg and Hammer (2012) both argued that availability of essential replacement components for solar PV systems is a major challenge because of lack of rural markets. One participant at Umodzi CBO explained that:

> "An inverter was burnt at the CDSS and the RET contractor was called from Blantyre to come and replace the inverter and was paid MK145, 000.00 for the inverter and MK20,000.00 for allowances".

Another participant at Kuntiyani CBO explained that:
> "We buy minor spare parts like water taps when they get damaged from   Balaka district but for essential replacement components like water pump, the contractor is invited to do the maintenance work from Lilongwe".

The statements indicate that the CSPV system essential replacement components namely PV modules, batteries, inverter, charge controller, water pump and pump controller cannot be purchased from nearest trading centres. The first implication of this is that CBOs are paying additional costs to replace CSPV system components. For example, the final end-customer price for the inverter was less than MK100,000.00 in 2015 (see Figure 4.3) while it costs about MK165,000.00 for the contractor to travel from Blantyre to replace the faulty inverter. Secondly, there is a loss of income and time that is wasted waiting for the contractor to travel to the CSPV systems to do maintenance works. Income is also lost when minor components need replacement such as water tap as someone has to hire a bicycle taxi to travel to the nearest trading centre.

This study also noted that the CSPV systems were installed in the remotest areas where there is no public transport. The CSPV system being a new concept, essential replacement components can hardly be found at nearest trading centres except for minor components such as light bulbs and water taps. Participants at Umodzi CBO narrated that they travel by bicycle taxis to Nsanama Trading Centre which is a distance of 23km to get public transport to either Zomba, Blantyre or Lilongwe. At Kuntiyani CBO, participants reported that to get public transport to the cities, one has to first of all travel by bicycle taxis over 50km to Balaka. The roads to both CBOs are very poor and characterised by lack of properly constructed bridges. One participant at Umodzi CBO raised a concern over poor roads as follows:
> "We wake up around 3 O'clock in the morning just to hire bicycle taxi to take us to Nsanama Trading Centre to get public transport to Zomba or Blantyre".

Participants at Kuntiyani CBO indicated that they pay close to MK6,000.00 and MK10,000.00 to travel to Balaka and Lilongwe city respectively to purchase solar lanterns. The results are contrary to Ondraczek (2011) who indicated that sources and logistics of replacement solar PV system components should be conducive to encourage widespread uptake of CSPV systems. However, the results agree with Ahlborg and Hammar (2011) that one of the barriers to CSPV systems maintenance needs is unavailability of rural market.

In summary, this study noted that essential replacement components for the CSPV systems cannot be purchased within the locality of the CSPV systems because of lack of rural markets for solar PV system components. This is evident from the list of Licensed Energy Operators in Malawi in December, 2015 which indicated that there were 31

certified renewable energy companies but most of them were based in the cities of Blantyre, Zomba, Lilongwe and Mzuzu (MERA, 2014). For example, information from participants was that the essential replacement components were mainly purchased in Lilongwe but BOS components could be purchased at nearest trading centres. It was also reported that in the study areas there were no public transport, and road conditions were very poor. Therefore, travelling to purchase replacement components is difficult and expensive.

### 4.3.3   *IGA earnings from installed CSPV system*

Figure 4.5 illustrates the following: at Kuntiyani CBO selling of solar lanterns is ranked the highest with earnings of MK648,000.00 (63%). Phone charging is ranked second with MK172,800.00 (17%). Drawing water is ranked with MK120,000.00 (11%). TV shows is ranked lowest with MK96,000.00 (9%). The net IGA earnings for 2014 / 2015 are MK913,400.00 and MK492,000.00 for Kuntiyani and Umodzi CBOs respectively. These IGA earnings exclude capital costs, maintenance (labour, transport and subsistence allowances) and operational costs. The detailed calculations for IGA earnings at Kuntiyani and Umodzi CBOs are illustrated in Appendix H (Item 1.0 to 3.0). Figure 4.5 reveals that IGAs taking place at Kuntiyani and Umodzi CBOs are a mixture of those directly linked to the installed CSPV systems and others which are not related to the systems. The IGAs that are directly linked to the CSPV systems are phone charging, TV shows and drawing water where people pay for the services provided. Selling of solar lanterns is the IGA that is not related to the installed CSPV systems. The figure also reveals that at Kuntiyani CBO the IGA earnings that are not directly linked with the installed CSPV systems are greater than those that are directly linked.
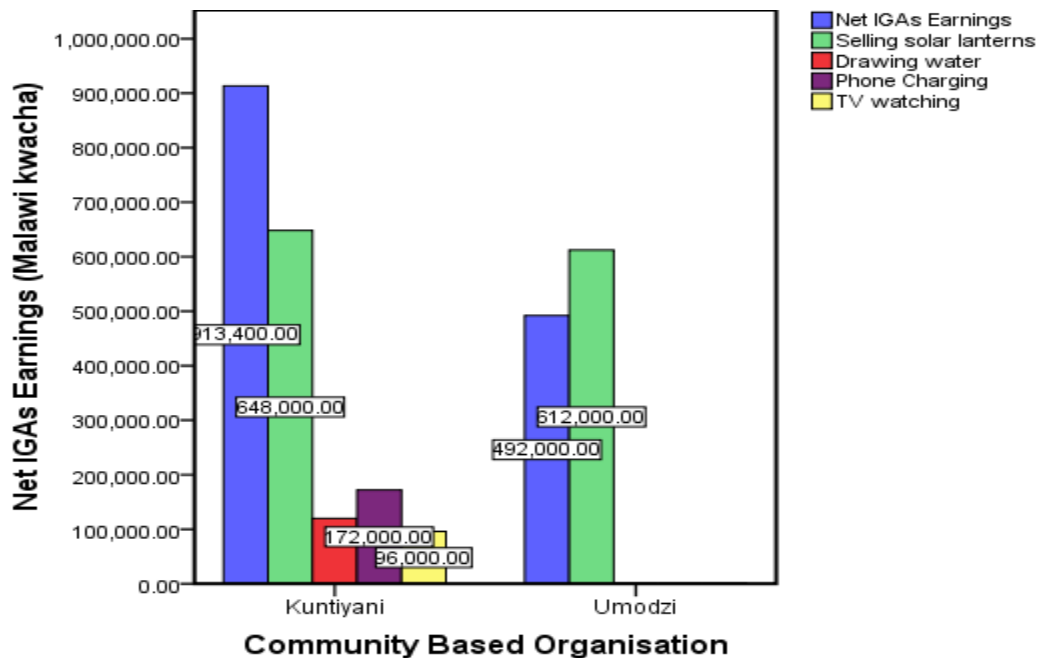


**Figure 4.5:-** Kuntiyani and Umodzi CBOs CSPV systems IGA Earnings 2014 / 2015

The detailed calculations in Appendix H - Table H1 indicate that purchase of solar lanterns occurred on one occasion at Kuntiyani CBO. At Umodzi CBO it occurred three times but accounts records for the third occasion had not been reconciled at the time of data collection. When asked why the data was not reconciled, one participant said the following:

> "Solar lanterns were sold on credit therefore we are waiting for people to make
>  payment to reconcile the account records".

One of the disadvantages of system owner business model highlighted in the literature review is that sustainability of the model might be affected by some people's influential behaviour (CES and MUREA, 2014). This is evident at Umodzi CBO where energy committee members are not allowed to undertake IGAs directly linked to the CSPV system such as phone charging. On this issue one of the participants had this to say:

"The teachers do not want to see us near the school. Sometimes they chase us away for fear of theft and disturbing institutional activities. Therefore, we cannot do phone charging IGA".

Other participants also said:

"Even if we do the phone charging IGA people are also not willing to pay for the services already there is lighting in the staff houses but it is not paid for. They feel it is a donation from well-wishers to the institutions. Others do not trust the energy committee members because they feel we mismanage the revenue. Hence, selling of solar lanterns is the only IGA taking place at Umodzi".

The two CSPV systems were appraised using Net present Value (NPV) capital investment appraisal technique. The NPV is a measure of how much value is created or added by undertaking an investment (Schwalbe, 2009). The Net Present Values (NPVs) were calculated using even net IGA earnings obtained for 2014 / 2015 of MK913,400.00 and MK492,000.00 for Kuntiyani and Umodzi CBOs respectively for a period of 10 years (see Appendix H - Table H3 and H4). The tables show that the NPV values for both CSPV systems are negative. This means that the net IGA earnings are not adequate to recover the investment capital costs in 10 years. The NPVs were supposed to be greater than or equal to zero for the CSPV systems to be considered successful (Schwalbe, 2009). The results indicate that the two CSPV systems are system-owner business models whose main aim of undertaking IGAs is not for profit making but to finance operation and maintenance of the system (Francis et al., 2008).

**Table 4.10:-** Itemised final end-customer prices of essential replacement components for single battery-based and water pumping systems

| Item | Component | Quantity | Unit Final end-customer price (MK) - December, 2016 | Final end-customer price (MK) - December, 2016 |
|------|-----------|----------|-----------------------------------------------------|-------------------------------------------------|
| **Single battery-based system** | | | | |
| 1 | PV module (100W) | 2 | 113,905.00 | 227,810.00 |
| 2 | Battery (96Ah) | 1 | 161,865.00 | 161,865.00 |
| 3 | Inverter | 1 | 118,701.00 | 118,701.00 |
| 4 | Charge controller (20A) | 1 | 58,751.00 | 58,751.00 |
| **Total** | | | | **567,127.00** |
| **Single Water pumping system** | | | | |
| 1 | PV modules (85W) | 8 | 97,119.00 | 776,952.00 |
| 2 | Water pump | 1 | 1,798,500.00 | 1,798,500.00 |
| 3 | Pump controller | 1 | 539,550.00 | 539,550.00 |
| **Total** | | | | **3,115,002.00** |

Table 4.10 illustrates the breakdown of essential replacement component final end-customer prices of single battery-based and water pumping system as of December, 2016. The unit final end-customer prices for the month of December, 2016 were calculated using the compounding formula. Appendix H - Item 5.0 illustrates the detailed calculations. The results indicate that the net IGA earnings obtained for 2014 / 2015 of MK913,400.00 and MK492,000.00 is not adequate to finance replacement of essential components for single battery-based and water pumping systems illustrated in Table 4.10 but cumulative net IGAs earnings over several years as illustrated in Appendix H - Table H3 and H4) can finance replacement of essential components.

The results of this study contradict Jacobson (2007), who reported that solar PV system electricity is still inadequate in supporting economically productive activities. Jacobson (2007) report implied that no economic activities can be done using solar PV-system electricity while the study has given optimistic results that CSPV system electricity can support economic activities through net cumulative IGA earnings. However, the results agree with Phiri (2014) who revealed that the role of solar PV system electricity in IGAs is satisfactory. Konkle (2014) highlighted that CSPV systems requires funding for maintenance to ensure economic sustainability and highlighted improper defined IGAs and inadequate funding as the main reasons of failure. The results indicate that there were properly defined IGAs at Kuntiyani CBO and Umodzi CBOs although only the selling of solar lanterns is taking place at Umodzi CBO. As a

matter of supporting the CBOs in the long-term, favourable financial arrangements were also put in place for example, the CBOs were given initial capital to purchase and sell solar lanterns to enhance income.

There are some external factors that led to the adequate IGA earnings and these were community acceptance, community involvement and capacity building. The CBOs accepted by agreeing to form energy committees after the award of the projects. The CBOs identified IGAs that could raise funds for replacement of components, operation and maintenance costs of the systems. Keeping of IGA accounts records also indicates a sense of ownership, attitude and perception towards CSPV systems (Phiri, 2014). In terms of community involvement, the CBOs were involved in decision making right from the beginning, for example, during needs assessment. The CBOs also comprised different stakeholders such as VDC, SMC and PTA as indicated in Section 3.3.3, therefore, decisions came from all sectors of the community. In terms of capacity building before Kuntiyani and Umodzi CBOs CSPV systems were installed, committee members visited Nsimuko CBO in Balaka in order to appreciate what their friends were doing. They were also taught leadership and business skills to enable them manage account records.

### 4.4 Chapter summary:-
This chapter has presented and discussed compliance of the installed CSPV system components with MBS specifications, replacement component final end-customer price trends, sources and logistics and IGA earnings at Kuntiyani and Umodzi CBOs. The next chapter will draw conclusions and make recommendations resulting from the study.

### Chapter 5:- Conclusions and Recommendations
### 5.0 Introduction:-
This study examined the installed CSPV system component specifications, final end-customer price trends, availability and associated IGAs to ensure economic sustainability of the systems at Kuntiyani and Umodzi CBOs. The study was guided by four objectives and four research questions. The aim of this chapter is to draw conclusions, make recommendations and provide directions for further research.

### 5.1 Summary of findings:-
*5.1.1 Compliance of the installed CSPV system components with MBS specifications*
The study found out that the installed essential components at Kuntiyani and Umodzi CBOs CSPV systems complied with the MS battery-based and water pumping system specifications. In addition, the study found that common mistakes that occur at different stages of implementing solar PV systems from site selection to safety and service as outlined in Table 4.7 were also reduced.

*5.1.2 Final end-customer price trends of replacement components*
The results of this study revealed that despite the duty free status on all renewable energy products in Malawi, the final end-customer price trends of the installed essential solar PV system components namely PV module, battery, charge controller, inverter, water pump and pump controller showed moderate increases between May, 2014 and December, 2015 period. The increases were due to cost insurance and freight (CIF) and other costs because all the components are imported and there were currency fluctuations.

*5.1.3 To establish the replacement component sources and logistics at Kuntiyani and Umodzi CBOs*
The results of this study revealed that replacement components cannot be purchased within the locality of the CSPV systems because of lack of rural markets for solar PV system components. The essential replacement components for maintenance needs for both CSPV systems are mainly purchased from the Lilongwe city. Non-essential components are purchased at the nearest trading centres to the installed CSPV systems. In addition, roads are in poor condition, as a result, there are no public transport to both Kuntiyani and Umodzi CBOs. The only means of transport is unreliable private vehicles and bicycle taxis but the charges are exorbitant. The study also revealed that the CBOs call for RET contractors who installed the systems to perform major maintenance works while energy committee members were trained to perform minor maintenance works. The problem with this arrangement is that income is lost towards transport costs for the RET contractor. It also takes time for the RET contractors to travel and fix the problem. This also results into loss of revenue.

*5.1.4   Income Generating Activity Earnings at Kuntiyani and Umodzi CBOs*

This study found out that the annual net IGA earnings from Kuntiyani and Umodzi CBOs CSPV systems are inadequate to recover the investment capital costs. For example, the total itemised final end-customer prices of essential replacement components for single battery-based and water pumping solar PV systems (see Table 4.10) are greater than the net IGA earnings for Kuntiyani and Umodzi CBOs (see Appendix H - Item 4.0). The study also found out that cumulative net IGA earnings over the years at Kuntiyani and Umodzi CBOs CSPV systems can finance operation and maintenance of the CSPV systems, which includes replacement of the essential components because the installed essential components have varying life expectancy (see Table 4.5), as a result, will not be replaced at the same time. For example, the net IGA earnings over several years can be added together to meet the cost of replacement of essential CSPV system components (see Appendix H - Item 6.0). The results also revealed that the IGA earnings come from both IGAs that are directly linked and those that are not related to the installed systems.

**5.2   Conclusions:-**

Based on the results of this study it can be concluded that the installed CSPV system component specifications, their final-end customer price trends and IGA earnings can ensure economic sustainability at Kuntiyani and Umodzi CBOs. However, the unavailability of replacement components impede economic sustainability due to lack of rural markets for the installed components because the concept is new; and the roads leading to the CBOs are in poor condition.

**5.3   Recommendations:-**

Based on the findings and conclusions, the study makes the following recommendations.

(a)     All CSPV system replacement components should be inspected to make sure that Malawi Bureau of Standard specifications are maintained and that common mistakes that occur at different stages of implementing solar PV systems do not appear. CES and MUREA (2014) revealed that there are a lot of sub-standard solar PV system products on the market due to increase in demand of RETs. Although Table 4.1 is showing full compliance of the installed CSPV system Components but the reality is that some manufacturers of imported technologies follow standards while others manufacture cheaply and export to developing countries that do not have adequate standards and certification bodies (Emodi, Yusuf and Boo, 2017).

(b)     Introduction of duty on RET products will help reduce importation of sub-standard RET products and at the same time increase revenue in Malawi. Emodi et al. (2014) highlighted that many industrialised countries have increased their production capacity of RET products due to increased demand in developing countries. Therefore, there is need to re-visit government policies in order to prevent the importation of sub-standard RET products.

(c)     Encouraging private traders in the rural areas to register with MERA in order to import and sell renewable energy products. This will help creation of solar PV system components markets in rural areas and make it easy for CBOs to purchase CSPV system replacement components within their locality.  Ahlborg and Hammar (2011) highlighted that one of the barriers to CSPV systems is lack of rural markets for solar PV system components. This will, therefore, reduce transport costs thereby increasing IGA earnings.

(d)     Improving rural access roads to ease travelling to the rural areas. This will encourage the private sector to gain interest and open up rural markets for RETs products (Ahlborg and Hammar, 2011). This will save CBOs from travelling long distances to purchase RET products.

(e)     Creating additional IGAs such as internet bureaus, soft drink selling and irrigation farming using overflow water at Umodzi and Kuntiyani CBOs respectively to increase IGA earnings per annum. Currie et al. (2012) highlighted that IGAs increase revenue for operation and maintenance of the solar PV systems.

**5.4   Directions for Further Research:-**

The study was conducted just a year after the pilot CSPV systems were installed, therefore a similar study should be done after some years to compare the findings especially in the area of final end customer price trends, sources and logistics, and IGA earnings. The following are other areas of further study:

(a) The impact of the installed CSPV systems on either education or health institutions. Such a study will assess the positive and negative effects the CSPV system has brought on the education or health institution. Results will encourage GoM and NGOs to install CSPV systems in other areas where there is no grid-electricity.

(b) The installed CSPV systems technical performance and efficiency. This area of study is about examining the CSPV systems to find out if they are giving out the expected output in terms of electricity or water. Such a study might help the system designers to know which areas to improve in order to increase efficiency.

(c) The constraints and challenges faced by the installed CSPV systems in Malawi. This area of study could investigate the challenges faced by the installed CSPV systems. The results of the investigations might assist in formulating recommendations that could help management come up with measures to minimise the challenges.

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## Appendices

**Appendix A:   Solar PV System Standards**

**Table A1:-** Major IDCOL requirements

| Item | Component | IDCOL requirements | Remarks |
|---|---|---|---|
| 1 | PV Module | Module number | PV-TY705 A |
| | | Type of the module | Mono |
| | | Number of cells in series | 36 |
| | | Open circuit voltage (Voc) | 20.04V (at 750 W/m2) |
| | | Short circuit current (Isc) | 4.05A (at 750 W/m2) |
| | | Rated peak power (Pmax) | 69W |
| | | Maximum operating voltage (Vm) | 20A |
| | | Maximum operating current (Im) | 3.1A |
| | | Short circuit current Temp | Coefficient in mA/oC:0.135 |
| | | Open circuit Temp. | Coefficient in mA/oC:0.2 |
| | | Fill Factor (FF) | 0.576 |
| | | Test laboratory | BRACU Solar lab |
| | | Wind velocity withstanding capacity | 60Km/hr |
| | | Solar panel efficiency η (%) | 8.7% |
| 2 | | Battery model number | Volvo solar 80 |
| | | Battery low voltage: | 11.6V |
| | | Nominal voltage: | 12.6V |
| | | Battery gassing voltage | 13.3V |
| | | Max. Charging current (continuous): | 8A at 10hr |
| | | Capacity per battery at C/10 down to 1.75 per cell | 76Ah |
| | | Is the battery certified to standard? | Yes |
| | | Rated voltage: | 12V |
| | | Voltage regulation (Vr) high at voltage disconnect: | 14.34V |
| | | Voltage reconnect, for high voltage disconnect: | 13.67V |
| | | Is there a charging indicator? | Yes |
| | | Does it show battery, charging, system connect status? | Yes |
| | | Voltage drop between module and battery terminals at controller/regulator | 0.546V |
| | | LVD maximum current handling capacity | 22A |
| | | LVD: disconnect and reconnect voltage | 11.63V, 12.43V |
| | | Currents drawn with and without LEDs | 30mA with LED |
| | | Is there electronic over current protection? | Yes |

| | | Is there reverse polarity protection? | Yes |
|---|---|---|---|
| | | Is there electronic over current protection? | Yes |
| | | Is there lightening surge protection? | Yes |

**Table A2:-** Malawi Standard Solar PV battery-based specifications

| Description | Components | | | |
|---|---|---|---|---|
| | **PV module** | **Battery** | **Charge controller** | **Inverter (DC-AC)** |
| General/ technical characteristics | a) Type of module shall be single crystalline or poly- crystalline | Batteries shall be deep cycle vented or sealed (Valve regulated) type | Charging control: PWM with overcharge and over discharge protection. | The output voltage shall be 240VAC +-10% and a frequency of 50HZ |
| | b) Each module shall consists of 36 series-connected cells | Cycle life at several depth of discharge and Self discharge rate per month | Indication:Charging status, battery status (LV, LVD) Temperature compensation: -18 to -30mV/$^o$C | The output wave form shall be sine wave |
| | c) Each module shall have a bypass diode and equipped with a sealable waterproof IP54 junction box | Maximum charging voltage (cycling and floating) Final voltage, terminals shall be lug (bolt-nut) type | Set point voltages: LVD, LVR, HVD, HVR shall meet battery specifications | The efficiency shall be in excess of 85 percent (%) at above 50% load output |
| | e) Framed with an aluminium frame | | Equalisation | |
| | f) PV array shall consists of identical PV modules that could be replaceable | | Charge controller shall have a self-consumption of below 100mA or 1% of the rated capacity whenever is smaller | |
| Label | Manufacture name and address, model no., serial number, Ratings, Country of origin, Date of manufacturer | Manufacture name and address, model no., serial number, Ratings, Country of origin, Date of manufacturer | Manufacture name and address, model no., serial number, Ratings, Country of origin, Date of manufacturer | Manufacture name and address, model no., serial number, Ratings, Country of origin, Date of manufacturer |
| Circuit protection | | | Short circuit, reverse polarity, current leakage protection from battery to modules at night and surge protection | Surge, reverse polarity and short circuit protection |
| Warranty period | Warranty period of 10 years | Warranty period of 1 year | Warranty period of 2 years | Warranty period of 1 year |

**Table A3:-** Malawi Standard solar PV water pumping specifications

| Item | Description | | Components | |
|---|---|---|---|---|
| | | Pump | Controllers | Storage tank |
| 1 | General/Technical information | Self-priming and self and of lubricating centrifugal or positive displacement type | Indicators for system status for input power on or off, dry running, open circuit, over temperature and overload | Suitable durable, non-corrosive materials that shall not allow migration of the tank constituents into the water or react with water |
| | | Circuit protection for dry running, over voltage and under voltage, overload, and over temperature | Weather resistant and water tight. The water level sensor, tank sensor and any sensor in contact with water shall be non-corrosive | Designed to withstand the pressures when mounted and fully filled up. |
| | | Made of materials that are corrosion resistant | Clearly marked terminal for water supply, pump, earth leakage, and tank water level if have water level switch connection | Each tank shall be provided with drain and overflow outlets |
| | | The pump shall have a sand shroud to eliminate sand intrusion unless the pump is sand tolerant | Recommended cable size and length from the pump to controller, controller to pump and from the controller to the tank, minimum and maximum operating voltage, power consumption of efficiency | The tank capacity shall be approved indelibly and legibly marked on the tank |
| | | The pump shall have a sound pressure of less than 70 decibels (dB) Minimum and maximum operating current and voltage, power consumption, pumping rate, operating dynamic head, performance information and dimension and weight, eyelet, brief period and controller | | Towers and tanks shall be designed to withstand wind loads. The design shall be approved by a registered engineer and construction shall be done by a contractor registered with the construction regulatory authority and in accordance with the requirements of the local authorities |
| 2 | Labels | Manufacture name or model no., serial number, pump capacity, power rating, Country of origin, Date of manufacturer | Manufacturer name or model no., serial number, pump capacity, power rating, Country of origin, Date of manufacturer | - |

| 3 | Circuit protection | Short circuit, reverse polarity and overload protections | - | - |
| 4 | Warranty | Minimum warranty period for the pumps shall be not less than two years | | |

**Appendix B:   Inspection Sheets**
**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B1:-** General requirements for battery-based solar PV system specifications - PV modules (Adapted from MS 780:2007)

| GENERAL REQUIREMENTS FOR BATTERY-BASED SOLAR PHOTOVOLTAIC (PV) SYSTEM - SPECIFICATION | | | | |
|---|---|---|---|---|
| **PV MODULES** | | | | |
| **A.** | **General characteristics** | | | |
| **Item** | **Specifications** | **Status** | **Description** | **Remarks** |
| 1. | Are the PV modules single - Crystalline or poly-crystalline? | | | |
| 2. | Are the PV modules equipped with a sealable water proof IP54 Junction box? | | | |
| 3. | Are the PV modules framed with an aluminium frame (super straight structure) to allow secure connection to the PV array mounting structure? | | | |
| 4. | Is the PV array consisting of identical PV modules that would be replaceable? | | | |
| **B.** | **Technical characteristics** | | | |
| 1. | Does the PV modules have rated capacity? | | | |
| | Does the PV modules have Rated current? | | | |
| | Does the PV module have Rated voltage? | | | |
| **C.** | **Label** | | | |
| 1. | Is a Label provided? (I.e. Manufacturer's details, model/serial no. and ratings)? | | | |
| **D.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **E.** | **Warranty period** | | | |
| | Is the minimum warranty period 10 years? | | | |

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B2:-** General requirements for battery-based PV system specifications - Batteries (adapted from MS 780:2007)

| GENERAL REQUIREMENTS FOR BATTERY-BASED SOLAR PHOTOVOLTAIC (PV) SYSTEM - SPECIFICATION | | | | |
|---|---|---|---|---|
| **BATTERIES** | | | | |
| **A.** | **General characteristics** | | | |
| **Item** | **Specifications** | **Status** | **Description** | **Remarks** |
| 1. | Are the batteries deep cycle vented or sealed (Valve regulated) type? | | | |
| **B.** | **Technical characteristics** | | | |
| 1. | Is the rated capacity with indications of several | | | |

| | | | | |
|---|---|---|---|---|
| | discharge rates (at least C/20 discharge rate) provided for the Batteries? | | | |
| 2. | Is the cycle life at several depths of discharge (at least 30% depth of discharge provided)? | | | |
| 3. | Is the final voltage provided? | | | |
| 4. | Are the terminals lugged (Bolt-nut)? | | | |
| **C.** | **Label** | | | |
| 1. | Is a label provided? (I.e. Manufacturer's details, model/serial no. and ratings)? | | | |
| **D.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **E.** | **Warranty period** | | | |
| 1. | Is the minimum warranty period 1 year? | | | |

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B3:-** General requirements for battery-based solar PV system Specifications - Inverter (adapted from MS 780:2007)

| | | | |
|---|---|---|---|
| **GENERAL REQUIREMENTS FOR BATTERY-BASED SOLAR PHOTOVOLTAIC (PV) SYSTEM - SPECIFICATION** | | | |
| **INVERTER** | | | |
| **A.**    **Technical characteristics** | | | |
| **Item** | **Specifications** | **Status** | **Description** | **Remarks** |
| 1. | Is the output of the DC-AC inverter 240VAC+/- 10% 50Hz | | | |
| 2. | Is the output voltage a sine wave, efficiency of 85% at above 50% load output? | | | |
| **B.** | **Circuit protection** | | | |
| 1. | Is the DC-AC inverter supplied with protection (Reverse polarity and short circuit protection)? | | | |
| **C.** | **Label** | | | |
| 1. | Is a label provided? (i.e. Manufacturer's details, model/serial no. and ratings)? | | | |
| **C.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **D.** | **Warranty period** | | | |
| 1. | Is the minimum warranty period 1 year? | | | |

*Note: header row of this table has additional columns "Item | Specifications | Status | Description | Remarks"*

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**

**Table B4:-** General requirements for battery-based solar PV system specifications - Charge controller (adapted from MS 780:2007)

| | | | | |
|---|---|---|---|---|
| **GENERAL REQUIREMENTS FOR SOLAR PHOTOVOLTAIC (PV) PUMPING SYSTEM - SPECIFICATION** | | | | |
| **CHARGE CONTROLLER** | | | | |
| **A.**    **Physical characteristics** | | | | |
| **Item** | **Specifications** | **Status** | **Description** | **action** |
| 1. | Does the charge controller have charging control (overcharge and discharge protection)? | | | |

| 2. | Does the charge controller have indication status (charging status, battery status (Low voltage, low voltage disconnects)? | | | |
| **B.** | **Technical characteristics** | | | |
| 1. | Does the charge controller have set point voltages to meet battery specifications? | | | |
| 2. | Is the current rating provided? | | | |
| **C.** | **Circuit protection** | | | |
| 4. | Does the charge controller have Circuit protection: (short circuit, reverse polarity, reverse leakage current and surge protection? | | | |
| **D.** | **Label** | | | |
| 1. | Is a label provided? (i.e. manufacturer's details, model/serial no. and ratings)? | | | |
| **E.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **F.** | **Warranty period** | | | |
| 1. | Is the minimum warranty period 1 year? | | | |

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B5:-** General requirements for water pumping solar PV system specifications - Water pump (adapted from MS 780:2007)

| GENERAL REQUIREMENTS FOR SOLAR PHOTOVOLTAIC (PV) WATER PUMPING SYSTEM - SPECIFICATION | | | |
|---|---|---|---|
| **WATER PUMP** | | | |
| **A.** | **General characteristics** | | |
| **Item** | **Specifications** | **Status** | **Description** | **action** |
| 1. | Is the water pump self-priming and self- lubricating? | | | |
| 2. | Is the pump made of corrosion resistant materials | | | |
| 3. | Does the pump have a sound pressure of less than 70DB? | | | |
| **B.** | **Technical characteristics** | | | |
| 1. | Does the water pump have rated capacity? | | | |
| | Does the water pump have pumping rate? | | | |
| | Does the water pump have rated current and voltage? | | | |
| **C.** | **Circuit protection** | | | |
| 1. | Does the water pump have inbuilt circuit protection: (dry running, over /under voltage, overload and over temperature protection) | | | |
| **C.** | **Label** | | | |
| 1. | Is a Label provided? (i.e. Manufacturer's details, model/serial no. and ratings)? | | | |
| **D.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **E.** | **Warranty period** | | | |
| | Is the minimum warranty period 2 years? | | | |

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B6:-** General requirements for water pumping solar PV system specifications - Pump controller (adapted from MS 780:2007)

| GENERAL REQUIREMENTS FOR WATER PUMPING SOLAR PV SYSTEM - SPECIFICATION | |
|---|---|

| PUMP CONTROLLER | | | | |
|---|---|---|---|---|
| **A.**    **General characteristics** | | | | |
| **Ite m** | **Specifications** | **Stat us** | **Descriptio n** | **actio n** |
| 1. | Does the controller have indicators for system status? | | | |
| 2. | Is the controller weather resistant and water tight? | | | |
| 3. | Does the controller have clearly marked terminals/leads for the power supply, water pump, and earth leakage and tank water level? | | | |
| **B.** | **Technical characteristics** | | | |
| 1. | Does the controller have rated capacity? | | | |
| | Does the controller have rated current and voltage? | | | |
| **C.** | **Circuit protection** | | | |
| 1. | Does the water pump have inbuilt circuit protection: (short circuit, reverse Polarity and overload protection) | | | |
| **C.** | **Label** | | | |
| 1. | Is a Label provided? (i.e. Manufacturer's details, model/serial no. and ratings)? | | | |
| **D.** | **Lifespan** | | | |
| 1. | What is the life span? | | | |
| **E.** | **Warranty period** | | | |
| | Is the minimum warranty period 2 years? | | | |

**INSPECTION SHEET**
**(To be filled at the site by the Researcher)**
**Table B7:-** General requirements for battery-based solar PV system  Specifications - Storage tank (adapted from MS 780:2007)

| GENERAL REQUIREMENTS FOR SOLAR PHOTOVOLTAIC (PV) WATER PUMPING SYSTEMS - SPECIFICATION | | | |
|---|---|---|---|
| STORAGE TANK | | | |
| **A.**    **General characteristics** | | | |
| **Item** | **Specifications** | **Status** | **Description** | **action** |
| 1. | Is the storage tank made of durable, non-corrosive materials? | | | |
| 2. | Is the tank designed to withstand pressures when mounted and fully filled up? | | | |
| 3. | Is the tank capacity marked on the tank? | | | |
| 4. | Are drain and overflow outlets provided for each tank? | | | |
| 5. | Are the tower and tank design to withstand wind loads? | | | |

**Appendix C:   Questionnaire**

**Cover letter**

Please address all correspondence to
the Principal
**The Malawi Polytechnic**
**Private Bag 303**
**Chichiri**
**Blantyre 3**
**MALAWI**
Tel: (265) 870 411
Fax: (265) 870 578
Telex: 44613
E-Mail: principal@poly.ac.mw

14th November, 2015

Dear Respondent,

**RESEARCH: COMMUNITY SOLAR PHOTOVOLTAIC COMPONENT COST, AVAILABILITY AND INCOME GENERATING ACTIVITIES: CASE STUDY OF KUNTIYANI AND UMODZI CBOs IN BALAKA AND MACHINGA DISTRICTS IN MALAWI**

I write to seek your assistance in completing the attached questionnaire for MPhil dissertation on the above mentioned topic. The research forms part of the requirements for the Master of Philosophy degree at University of Malawi, The Polytechnic. The major objective of the study is to explore community solar photovoltaic system components specifications, their final end-customer prices, availability and associated income generating activities to ensure economic sustainability of the systems.

Everyone stand to benefit from the study as it will explore the installed pilot CSPV systems components specifications, replacement components final end-customer price trends, component sources and associated logistics and income generating activities earnings to ensure economic sustainability.

I would be very grateful if you could complete the attached questionnaire email it to annakamende@yahoo.com or call me on 088879871 / 0999 443 963. Needless to say, the information provided will be treated with strict confidentiality and names of individual Renewable Energy Technology suppliers will not be identified. I look forward to receiving your response.

Thank you in advance.

Yours faithfully,

**Anna Kamende**                                **Associate Professor Rhoda Bakuwa**
Student/Researcher                             Supervisor

**Section A – Background Information**
*(Please answer questions by clicking in the box and type Y)*

**1. How long has the company participated in importation and selling of Renewable Energy products?**

(a)  Less than a year…………………………………………….. ..…… ☐

(b)  1 - 5 years……………………………………………… ☐

(c)  6 - 10 years…………………………………………… ☐

(d)  11-15 years…………………………………………… ☐

(e)  More than 15 years…………………………………………… ☐

**2. What is the nature of your business?**

(a)  Wholesaler…………………………………………….... ☐

(b)  Retailer…………………………………………….. ☐

(c)  Both…………………………………………………… ☐

**3. Where is your business located?**

(a)  Lilongwe………………………………………………….. ☐

(b) Blantyre……………………………………………………….. ☐

(c) Other (specify)…………………………………………….

**4. Which of the following solar PV system components do you import and sell?**

(a). Solar Photovoltaic modules (panels)………………………………. ☐

(b). Batteries……………………………………................................ ☐

(c). Inverters………………………………………………….. ☐

(d). Charge controller………………………………………………… ☐

(e). Solar water pump………………………………………………… ☐

(f). Pump controller…………………………………………….. ☐

**Section B - CSPV system Component final end-customer prices (lighting and Water pumping)**

1. **What are the final end-customer prices of the components provided in the Table below?** (*Please fill in the table provided below*).

**Table C1:** Solar PV system component final end-customer prices

| Item | Component description | Rating | Final end-customer prices (MK) |
|---|---|---|---|
| 1 | Solar panel | 80W | |
| 2 | Solar panel | 100W | |
| 3 | Steca Regulator 12/24V | 20A | |
| 4 | Steca Regulator 12/24V | 30A | |
| 5 | Inverter | 600VA | |
| 6 | Raylite batteries | 96Ah | |
| 7 | Grundfos solar pump | 0.51KW | |
| 8 | Pump controller | 5W | |

2. **What government incentives are provided to solar PV components?** (*Click in the box and type Y*)

(a)  Subsidy………………………………………………………… ☐

(b)  Tax considerations…………………………………………….. ☐

(c)  Other (*Please specify*)……………………………………………… ☐
…………………………………………………………………..

3. **What comprise the final end-customer prices of the solar PV component costs**? (*Please fill the proportions in terms of percentage in the appropriate boxes provided*).

**(a) PV module**

**Table C2:-** Proportions of solar panels final end-customer price

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

**(b) Battery**

**Table C3:-** Proportions of Inverter final end-customer price

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

**(c) Inverter**

**Table C4:-** Proportions of batteries final end-customer price

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

**(d) Charge controller**

**Table C5:-** Proportions of charge controller final end-customer **price**

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

**(e) Water pump**

**Table C6:-** Proportions of solar water pump final end-customer price

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

**(f) Pump controller**

**Table C7:-** Proportions of pump controller final end-customer **price**

| Item | Description | Proportion (%) |
|------|-------------|----------------|
| 1 | Free on board (FOB) | |
| 2 | Cost Insurance and Freight (CIF) | |
| 3 | Licensee's mark up | |
| 4 | Other costs (specify) | |

4. What were the final end-customer prices of the components indicated in the Table below for the past 12 months? *Please fill in the table provided below where appropriate.*

**Table C8:-** Final end-customer prices of major solar PV system components

| | | | Component prices | | | | Grundfos Pump | Pump Controller |
|---|---|---|---|---|---|---|---|---|
| | **Modules** | | **Batteries** | **Inverter** | **Charge controller** | | | |
| **Month** | **80W** | **100W** | **96Ah** | **600VA** | 12/24V 20A | 12/24V 30A | **0.51KW** | |
| Jan'15 | | | | | | | | |
| Feb'15 | | | | | | | | |
| Mar'15 | | | | | | | | |
| Apr'15 | | | | | | | | |
| May'15 | | | | | | | | |
| Jun'15 | | | | | | | | |
| Jul'15 | | | | | | | | |
| Aug'15 | | | | | | | | |
| May'15 | | | | | | | | |
| Jun'15 | | | | | | | | |
| Jul'15 | | | | | | | | |
| Aug'15 | | | | | | | | |
| Sept'15 | | | | | | | | |
| Oct'15 | | | | | | | | |
| Nov'15 | | | | | | | | |
| Dec'15 | | | | | | | | |

**Appendix D:     Interview Guide for Focus Group Discussions**
**Consent form**
**Community Solar Photovoltaic Components Cost Availability and Income Generating Activities: Case Study of Kuntiyani and Umodzi CBOs in Balaka and Machinga districts**

Anna Betty Kamende
MPhil Scholar, University of Malawi- The Polytechnic

1.  We confirm that we have understood the information for the above study and
        have had the opportunity to ask questions.
2.  We understand that our participation is voluntary and that we are free to
        withdraw at any time without giving reasons.
3.   We agree to take part in the study.
        *(Please fill in your initials in the boxes provided)*

4.  We agree to the interview being audio recorded.
        *(Please tick the appropriate box)*
   (a) Yes ……………………………………….. ..…………………… ……….. ……………..
   (b)  No…………………………………………………………………………………………..
5.  We agree to the use of anonymised quotes where it is required.
    (a) Yes ……………………………………….. ..…………………… …………………………
    (b)  No…………………………………………………………………………………………..
Participants Representative:…………………..Signature:………………Date:……………………………
Researcher:………………………………Signature:………………Date:…………......................

**Opening the focus group discussions**
1.  Vote of thanks to the participants for considering the request for access and for
    agreeing to the meeting.
2.  A brief outline of the purpose of the research.
3.  The information to be obtained is for a Master of Philosophy degree research
    study and will be treated with confidentiality and anonymity where required.
4.  Request to record the interview electronically.
5.  Summary of the themes to be covered during the interview.
6.  Signing of the consent form.

**Section A: Demographic Information**
1.  Name of the CPSV system pilot project?...................................................................................................
2.  Region (North/Centre/South)……………………………………………………………………………
3.  District……………………………………………………………………..................................................
4.  Traditional Authority……………………………………………………………………….…………….
5.   Density (Rural / peri-urban / urban)…………………………………...................................................
6.  Nearest Trading Centre………………… …………………………………………………………………
7.  Physical location?...................................................................................................................................
8.  Number of participants?...........................................................................................................................
9.  Participants gender *(Write in the appropriate box)*

| Male | Female |
|------|--------|
|      |        |

10.   Participants age *(Write in the appropriate box)*

| 20 -30 years | 31 – 40 years | 41 – 50 years | Above 50 years |
|--------------|---------------|---------------|----------------|
|              |               |               |                |

11.   Participants experience in community development committees *(Write in the*

*appropriate box)*

| 0-5 years | 6-10 years | 11-15 years | 15-20 years | 21+ years |
|-----------|------------|-------------|-------------|-----------|

12. Personal involvement *(Write in the appropriate box)*

| CBO | PTA representative | Village Development Committee | School Management Committee | Teachers | Members |
|-----|--------------------|------------------------------|----------------------------|----------|---------|

13. Highest qualification

| Below Std 8 | Std 8 | JCE | MSCE | Certificate | Diploma | Degree | Post grad. |
|-------------|-------|-----|------|-------------|---------|--------|------------|

## Section B: Background Information
1. Brief description of type of the installed Solar PV system pilot project (water pumping or lighting), size (for example in kilowatts)?
2. When was the pilot CSPV system installed?
3. What were the terms of reference? Briefly explain?
4. What is the CBO organisation arrangement?
5. Who purchased the various components of the solar PV system?
6. What were the maintenance arrangements?
7. How would replacement components be procured?
8. What was the training arrangement?
9. What was the security arrangement after the installed solar PV system?

## Section C: Availability of CSPV system components (measured in terms of source and logistics
1. Where do (will) you buy replacement components for the CSPV system? Explain why?
2. What are the modes of transport available to purchase replacement components?
3. Explain more in terms of transport availability in your area?
4. How much do you pay for a return journey to buy replacement components?

## Section D: Income generating Activity (IGA) Earnings
1. What activities are undertaken by the CBOs to raise funds for replacement components?
2. If solar, lamp and battery charging are some of the IGAs, how much money is charged per item? How many of each item roughly are charged per day? Can I request to have data?
3. How are the finances managed? Can I request to have the records?
4. Which activity is currently playing an important role in income generation (for example bringing in more income)?

## Section E: Opinions
1. What constraints are there regarding:
- Component sources and logistics
- IGAs earnings.
- Please describe any other constraints?

2. What suggestions do you have regarding?
- Component sources and logistics.
- IGA earnings.
- Any other suggestions.

**Thank you for your cooperation**

**Appendix E:    Transcripts of focus group discussions**
**AE.1    Umodzi CBO focus group discussion transcript**
**Total focus group time:    3 hours**
**Moderator:**   Anna Kamende
**Participants:**   Energy committee members (A, B, C, D, E and F)

**Opening the focus group discussion:-**
**Moderator:** I think we should start, others will join us as they come. First of all let me thank you all for coming to this focus group discussion. The purpose of this focus group discussion is to obtain information for my study on the economic sustainability of the installed CSPV system at Umodzi CBO for my Master of Philosophy degree. The information obtained will be treated with confidentiality and no names will be mentioned in any part of the report. This discussion is being recorded electronically so I ask all of you to raise up your voices so that important information is well captured. The themes to be discussed include demographic information, background information, availability of CSPV system components (sources and logistics), income generating activities' earnings and opinion.

**Section A:     Demographic information**
**Moderator:**     What is the name of the CSPV system installed here?
**A:**   Umodzi CBO CSPV system.

**Moderator:**     In which region is Machinga district?
**A:**   Southern region.

**Moderator:**     Which district is this place?
**A:**   Machinga.

**Moderator:**     In which Traditional Authority (T/A) is Umodzi CBO CSPV system?
**A:**   T/A Kawinga.

**Moderator:**     How can you describe this area in terms of density, is it rural, peri- urban or urban?
**A:**   Rural.
**Moderator:**     Which is the nearest trading centre to this place?
**A:**   Nsanama Trading centre.

**Moderator:**     How many people are in the energy committee here at Umodzi CBO?
**A:**   We are about 10 members.

**Moderator:**     How many are you present here and where are the others?
**A:**   We are 6 members and the others we do not know whether they are coming or not but I informed everybody.

**Moderator:**     Do we agree with the information given?
**Others:**   Yes.

**Moderator:**     Out of 6 members you are here I can see that there are three ladies
                and three gentlemen. True?
**All:**   Yes.

**Moderator:**     How many participants are in the range of 20-30years? Please raise
                your hand. I can see a hand there.
**Moderator:**     How many participants are in the range of 31-40years? Three people.
**Moderator:**     How many participants are in the range of 41-50years? One person.
**Moderator:**     How many participants are in the range of 50+years? One person.
**Moderator:**     How many participants can rate themselves in the 0-5years category in terms of experience in community development committees such as Umodzi CBO CSPV system energy committee? Raise your hand.
**Moderator:**     Ooh one, two, and three and………..six. It seems all of you have 0-5 years of experience.

**Moderator:**      What is your highest academic qualifications? Let us start with those below standard 8. *Raise your hand*. None. Those with Standard 8 certificate? Three participants. Those with Junior Certificate of Education? One participant. Those with Malawi School Leaving Certificate of Education? One participant. Those with professional certificate? None. Those with Diploma? One participant.

**Section B:      Background information**
**Moderator:**     Can somebody give a brief description of the installed CSPV system project. Is it a water pumping system or battery-based lighting system and capacity in terms of kilowatts?
 **E:**     The CSPV system installed at Umodzi CBO is a battery-based system for lighting. Umodzi CBO CSPV system comprises of three institutions namely: Mpiranjala Primary School, Mpiranjala CDSS and Namanja Health Centre. I think participant C should give us the details from the record book.
 **C:**    Yes, the capacity of the installed CSPV system are as follows: primary School (100W), two systems at CDSS (160W each) and three systems at the health centre (300W, 300W and 600W).

**Moderator:**    When was the CSPV systems installed?
**B:**             May, 2014.

**Moderator:**     What were the terms of reference? Briefly explain?
**A:** At the beginning of this project student from The Polytechnic visited several CBOs including Umodzi CBO to assess the need for solar PV system electricity. Out of the many CBOs that were visited, Umodzi CBO was chosen and was asked to prepare a proposal to Scotland Community Energy organisation requesting for a grant to install the pilot CSPV system.  Umodzi CBOs energy committee was formed and went for training in leadership, business and solar PV installation management before a grant of about MK13,000,000.00 was given to the CBO. The development officer for Community Energy Malawi helped in the procurement process for the contractor who installed the CSPV system.

**Moderator:**     What is the CBO organisation arrangement?
**A:**    Umodzi CBO energy committee has about 10 members which include chairman, vice chairman, secretary, vice secretary, treasurer, committee members (3) and PTA representatives (2). Although we are only six people present here.

**Moderator:**    Who purchased the various components of the solar PV systems?
**A:**    The CEDP officer and some committee members went to Lilongwe to buy the components.
**Moderator:**    How would replacement components be procured?
**A:**    Replacement components are bought by the contractor who installed the system and stays in Blantyre.

**Moderator:**    How was the training arrangement?
**E:**    No training arrangement was done.

**Moderator:**    What was the security arrangement after the installed solar PV system?
**F:**    No security arrangement put in place. School and health centre guards provide security.

**Section C:     Availability of CSPV system components (measured in terms of source and logistics)**
**Moderator:**     Where do (will) you buy replacement components for the CSPV system? Explain why?
**A:**     Components can also be bought in Zomba and Blantyre which are the nearest cities. The reason is that the systems have just been installed therefore currently there are no spare parts at Nsanama Trading Centre.

**Moderator:**    What are the modes of transport available to purchase replacement components?
**D:**    Normally, one has to take a bicycle taxi to Nsanama Trading Centre which is about 23km from this place and get a minibus/Bus to Zomba, Blantyre, of Lilongwe depending on where you want to go.

**Moderator:**    Explain more in terms of transport availability in your area?
**B:**    Travelling to Nsanama Trading Centre is a problem because of the condition of the road. The road is bumpy and muddy during the rainy season and poor constructed bridges. If you want to travel to Zomba or Blantyre, we wake up around 3 O'clock in the morning just to hire bicycle taxi to take us to Nsanama Trading Centre to get public transport to Zomba or Blantyre.

**Moderator:**   How much do you pay for a return journey to buy replacement components?
**E:**   We have never gone to buy replacement components but the time an inverter was burnt at the CDSS we called the RETs contractor from Blantyre to come and replace the inverter and was paid MK145,000.00 for the inverter and MK20,000.00 for allowances.

**Section D:    Income generating Activity Earnings**
**Moderator:**   What activities are undertaken by the CBOs to raise funds for replacement components?
**C:**   Selling of solar lanterns.

**Moderator:**    Do we all agree?
**All:**   Yes

**Moderator:**    If selling of solar lanterns is the only IGAs, you are doing how much money is charged per item? How many of each item roughly are charged per day? Can I request to have data?
**C:**   I will share the accounts records.

**Moderator:**   How are the finances managed? Can I request to have the records?
**C:**   We were trained in business management skills so we use balance sheet to record the data. For example, the records are indicating that purchase of solar lanterns were three times but only two occasions have been balanced. The reason is that solar lanterns are sold on credit therefore we are waiting for people to make payment to reconcile the account records.

**Moderator:**   That is very good I need to take the records with me for detailed analysis of the IGAs you are doing. It is important to find out whether you are making profits or losses on any business.
**C:**   Solar lanterns were sold on credit therefore we are waiting for people to make payment to reconcile the account records.

**Moderator:**   Which activity is currently playing an important role in income
generation (for example bringing in more income)?
**C:**   Solar lanterns.

**Section E:   Opinion**
**Moderator:**   What constraints are there with regard to the following:

**Moderator:**    Component sources and logistics.
**F:**  Replacement components for the CSPV systems cannot be purchased within the locality of the CSPV systems because there are no rural markets for solar PV system components.  In addition no public transport and the road condition is very poor in this area therefore, travelling to purchase replacement components is difficult and expensive.

**Moderator:**   IGA earnings.
**A:**    The teachers do not want to see us near the school. Sometimes they chase us away for fear of theft and disturbing institutional activities. Therefore, we cannot do phone charging IGA.
**B:**    Even if we do the phone charging IGA people are also not willing to pay for the services already there is lighting in the staff houses but it is not paid for. They feel it is a donation from well-wishers to the institutions. Others do not trust the energy committee members because they feel we mismanage the revenue. Hence, selling of solar lanterns is the only IGA taking place at Umodzi.
**Moderator:**    Please describe any other constraints?
**F:**  1. Capacity of the CSPV systems are not adequate for equipment like kettle, refrigerator, sterilizer and vacuum extractor.
2. Misunderstanding between the energy committee and personnel at the two institutions in terms of contributions towards maintenance of the installed CSPV systems.
3. Theft and vandalism.
4. No training in technical skills took place for the energy group to maintain the CSPV system.

**Moderator:**   What suggestions do you have regarding?

**Moderator:**    Component sources and logistics.
**A:**    Opening up rural markets for solar PV system components and improving the road networks in rural areas.
**Moderator**:    IGA earnings.
**B:**    The CSPV system should be installed at an independent place and not at the institution to allow energy committee members to work independently.

**Moderator:**    Any other suggestions.
**F:**    Increasing capacity of the CSPV systems and improving the road from Nsanama Trading Centre to this place to make travelling easy.

**Moderator:**    I think we have reached the end of our discussion. Let me have the records as requested. Thank you very much for your participation.

**AE.2    Kuntiyani CBO focus group discussion transcript**
**Total focus group time:    3 hours**
**Moderator:**    Anna Kamende
**Participants:**    Energy committee members (A, B, C, D, E, F,G,H,I,J, K and L)
**Opening the focus group discussion**
**Moderator:**    I welcome you all to this focus group discussion. The purpose of this focus group discussion is to obtain information for my study on the economic sustainability of the installed CSPV system at Umodzi CBO for my Master of Philosophy degree. Let me highlight that the information obtained will be treated with confidentiality and no names will be mentioned in any part of the report. This discussion is being recorded electronically so I ask all of you to raise up your voices so that important information is well captured. The themes to be discussed include demographic information, background information, availability of CSPV system components (sources and logistics), income generating activities' earnings and opinion.
**Section A:    Demographic information**
**Moderator:**    What is the name of the CSPV system installed here?
**A:**    Kuntiyani CBO CSPV system.

**Moderator:**    In which district is Kuntiyani CBO CSPV system district?
**A:**    Balaka.
**Moderator:**    In which region is Balaka district?
**A:**    Southern region.

**Moderator:**    In which Traditional Authority (T/A) is Kuntiyani CBO CSPV system?
**A:**    T/A Kuntiyani.

**Moderator:**    How can you describe this area in terms of density, is it rural, peri-urban or urban?
**A:**    Rural.
**Moderator:**    Which is the nearest trading centre to this place?
**A:**    MbelaTrading Centre.

**Moderator:**    How many people are in the energy committee here at Kuntiyani CBO?
**A:**    We are about 12 members. Two representatives each from the following groups: CBO, VDC, Chiefs, mother group, PTA and teachers.

**Moderator:**    These people are the ones gathered here?
**A:**    Yes.

**Moderator:**    Do all of us agree with the information that is being given?
**Others:**    Yes.

**Moderator:**    Can someone tell us how many males and females are gathered here? I think another person should give us the figures.
**K:**    8 males and 4 females

**Moderator:**    How many participants are in the range of 20-30years?
**K:**    Three people.

**Moderator:**    How many participants are in the range of 31-40years?
**K:**    Five people.

**Moderator:**    How many participants are in the range of 41-50years? One person.
**K:**    Three people.

**Moderator:**    How many participants are in the range of 50+years? One person.
**K:**    One person.

**Moderator:**    How many participants can rate themselves in the 0-5years category in terms of experience in community development committees such as Umodzi CBO CSPV system energy committee? Raise your hand.
**K:**    12 people.

**Moderator:**    What is your highest academic qualifications? Starting with below Standard 8.
**K:**    One person.

**Moderator:**    Standard 8? Three participants.
Moderator:   Junior Certificate of Education?
**K:**    Two participants.

**Moderator:**    Malawi School Leaving Certificate of Education?
**K:**    Two participants.
Moderator:   Professional certificate?
**K:**    None.

**Moderator:**    Diploma?
**K:**    Two participants.
**Section B:    Background information**
**Moderator:**    Can somebody give a brief description of the installed CSPV system project. Is it a water pumping system or battery-based lighting system and capacity in terms of kilowatts?
**D:**    The solar PV systems installed at Kuntiyani CBO are both battery-based system for lighting and water pumping. The CSPV sytem consists of a 0.64-kilowatt (kW) solar PV water pumping system and number (1no.) x 85 watts (W), 4no. x 170W and 1no. x 340W battery-based solar PV systems and were installed at cost of thirty-two million Malawi Kwacha (MK32,000,000.00).

**Moderator:**    When was the CSPV systems installed?
**B:** The water pumping system was installed in 2014 but started working in December, 2015.

**Moderator:**    What were the terms of reference? Briefly explain?
**A:**    Before the beginning of this project, a need assessment was conducted by CEDP officer in three CBOs to find out the priority needs of this area. It was found out that the area lacked water and electricity. Out of the three CBOs that were assessed, Kuntiyani CBO was chosen to work with CEDP. Kuntiyani CBO energy committee was formed and was requested to prepare a proposal requesting for a grant from Scotland. The energy committee members were then trained in solar PV system basics and business skills. The amount of the grant was MK32,000,000.00. The CEDP officer helped in the procurement process of the contractor to install the system.

**Moderator:**    What is the CBO organisation arrangement?
**A:**    Chairman, vice chairman, secretary, vice secretary, treasurer and the others are committee members.

**Moderator:**    Who purchased the various components of the solar PV systems?
**B:**    The CEDP officer and some committee members went to Lilongwe to buy the components.

**Moderator:**    How would replacement components be procured?

**L:** We buy minor spare parts like water taps when they get damaged from Balaka district but for large items like water pump, the contractor invited to do the maintenance work from Lilongwe".

**Moderator:** How was the training arrangement?
**E:** No training arrangement was done.

**Moderator:** What was the security arrangement after the installed solar PV system?
**F:** We have night security guard.

**Section C: Availability of CSPV system components (measured in terms of source and logistics)**
**Moderator:** Where do (will) you buy replacement components for the CSP system? Explain why?
**A:** We buy minor spare parts like water taps when they get damaged from Balaka district but for large items like water pump, the contractor is invited to do the maintenance work from Lilongwe.

**Moderator:** What are the modes of transport available to purchase replacement components?
**D:** Normally, one has to take a bicycle taxi to Balaka which is about 62km from this place and get a minibus/Bus to Lilongwe.

**Moderator:** Explain more in terms of transport availability in your area?
**G:** Travelling to Balaka is a problem because there is no reliable transport due to poor road condition.

**Moderator:** How much do you pay for a return journey to buy replacement components?
**E:** It costs about MK6,000.00 for one to travel to Balaka and MK10,000 to Lilongwe return journey.

**Section D: Income generating Activity Earnings**
**Moderator:** What activities are undertaken by the CBOs to raise funds for replacement components?
**J:** Selling of solar lanterns, phone charging, drawing water and TV watching.
**Moderator:** If selling of solar lanterns is the only IGA, you are doing how much money is charged per item? How many of each item roughly are charged per day? Can I request to have the accounts records?
**I:** Most of the records for the IGAs are with the treasurer but just as an example for drawing water each family pays Mk300 per year.
**Moderator:** How many families?
**I:** 170 families.

**Moderator:** How are the finances managed? Can I request to have the records?
**H:** I have the account records with me let me share the details.

**Moderator:** I think share me after the discussion. The records will help me in further analysis of the IGA earnings.

**Moderator:** Which activity is currently playing an important role in income generation (for example bringing in more income)?
**C:** Selling of solar lanterns.

**Section E: Opinion**
**Moderator:** What constraints are there with regard to the following:

**Moderator:** Component sources and logistics.
**F:** Replacement components are not found locally, one has to travel to Balaka or Lilongwe in so doing income is lost.

**Moderator:** IGA earnings.
**A:** Institutions do not allow us to engage in other IGAs such as battery charging, barber shops at their premises for fear of disturbing their activities.
**Moderator:** Please describe any other constraints?

**F:** Sometimes the tanks are not filled with water to capacity especially during cloudy days therefore, the water is not enough to meet the demand.

**Moderator:** What suggestions do you have regarding?

**Moderator:** Component sources and logistics.

**A:** 1. Replacement components such as water pump should be found locally other than Lilongwe.

2. Roads should be maintained to allow RET traders to open up their businesses in rural areas.

**Moderator:** IGA earnings.

**B:** The CSPV system should be installed at an independent place and not at the institution to allow energy committee members to work independently.

**Moderator:** Any other suggestions.

**F:** 1. Increasing the number of water storage tanks to have sufficient water.

    2. Training in technical skills should place for the energy committee members to
       be able to maintain the CSPV system.

**A**: Pipe layout must be redesigned so that when one pipe line is faulty it should not affect the other lines.

**Moderator:** This is the end of our discussion. Can I have the accounts records?

**Thank you very much for your participation.**

**Appendix F: Replacement essential components final end-customer prices and trends**

**Table F1:-** Replacement essential components final end-customer prices in May, 2014

| Item | Component description | Rating | Final end-customer prices (MK) |
|---|---|---|---|
| 1 | PV module | 80W | 65,000.00 |
| 2 | PV module | 100W | 79,000.00 |
| **Average = (65,000.00 + 79,000 / 2)** | | | 72,000.00 |
| 3 | Steca Regulator 12/24V | 20A | 29,000.00 |
| 4 | Steca Regulator 12/24V | 30A | 35,000.00 |
| **Average = (29,000.00 + 35,000.00 / 2)** | | | 32,000.00 |
| 5 | Inverter | 600VA | 89,000.00 |
| 6 | Raylite batteries | 96Ah | 79 000.00 |
| 7 | Grundfos solar pump | 0.51kW | 1,375,250.00 |
| 8 | Pump controller | 5W | 391,000.00 |

**Table F2:-** Replacement essential components final end-customer price trends in Malawi 2014 / 2015

| Component prices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Month** | **Modules** | | **Batteries** | **Inverter** | **Charge controller** | | **Grundfos Pump** | **Pump Controller** |
| | **80W** | **100W** | **96Ah** | **600VA** | **12/24V 20A** | **12/24V 30A** | **0.51kW** | **5W** |
| **Malawi Kwacha (MK'0.00)** | | | | | | | | |
| May'14 | 65,000 | 79,000 | 79,000 | 89,000 | 29,000 | 35,000 | 1,375,250 | 391,000 |
| June'14 | 65,000 | 79,000 | 79,000 | 89,000 | 29,500 | 35,000 | 1,375,250 | 391,000 |
| July'14 | 65,000 | 79,000 | 79,000 | 89,000 | 29,500 | 35,000 | 1,375,250 | 391,000 |
| Aug'14 | 75,000 | 89,000 | 95,000 | 90,000 | 29,500 | 35,000 | 1,400,000 | 391,000 |
| Sept'14 | 75,000 | 89,000 | 95,000 | 90,000 | 30,000 | 35,000 | 1,400,000 | 391,000 |
| Oct'14 | 75,000 | 89,000 | 95,000 | 90,000 | 30,000 | 35,000 | 1,400,000 | 395,000 |
| Nov'14 | 75,000 | 89,500 | 99,000 | 95,000 | 35,000 | 35,000 | 1,400,000 | 395,000 |
| Dec'14 | 76,000 | 90,000 | 99,000 | 95,000 | 35,000 | 35,000 | 1,400,000 | 395,000 |
| Jan'15 | 76,500 | 90,000 | 105,000 | 95,000 | 35,000 | 35,500 | 1,450,000 | 400,000 |

| Feb'15 | 76,500 | 92,000 | 105,000 | 95,000 | 35,500 | 40,000 | 1,450,000 | 400,000 |
| Mar'15 | 77,000 | 95,000 | 105,000 | 95,000 | 36,000 | 45,000 | 1,450,000 | 400,000 |
| Apr'15 | 78,000 | 95,000 | 105,000 | 95,000 | 36,000 | 49,500 | 1,450,000 | 400,000 |
| May'15 | 78,000 | 95,000 | 105,000 | 95,000 | 36,500 | 49,500 | 1,450,000 | 400,000 |
| Jun'15 | 79,000 | 95,000 | 105,000 | 97,500 | 37,500 | 50,000 | 1,450,000 | 400,000 |
| July'15 | 80,000 | 95,000 | 110,000 | 97,500 | 39,500 | 50,000 | 1,450,000 | 400,000 |
| Aug'15 | 80,000 | 95,000 | 115,000 | 97,500 | 45,000 | 55,000 | 1,450,000 | 400,000 |
| Sept'15 | 80,000 | 95,000 | 120,000 | 97,500 | 49,000 | 59,000 | 1,450,000 | 450,000 |
| Oct'15 | 80,000 | 95,000 | 125,000 | 99,000 | 49,000 | 65,000 | 1,500,000 | 450,000 |
| Nov'15 | 80,000 | 95,000 | 125,000 | 99,000 | 49,000 | 69,000 | 1,500,000 | 450,000 |
| Dec'15 | 81,000 | 95,000 | 135,000 | 99,000 | 49,000 | 69,000 | 1,500,000 | 450,000 |

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Chichiri
Blantyre 3

Date: 15th September, 2015

Dear Sir/Madam,

**TO WHOM IT MAY CONCERN**

**LETTER OF INTRODUCTION FOR ANNA KAMENDE (MPHIL STUDENT)**

I write to certify that **Anna Kamende** is a Master of Philosophy (Renewable Energy) student at University of Malawi - The Polytechnic undertaking a research on the topic "**Community Solar Photovoltaic Components Cost, Availability and Income Generating Activities: Case Study of Kuntiyani and and Umodzi CBOs in Balaka and Machinga Districts in Malawi**". As a result she would like to collect data from your organization and other relevant key informants to assist her complete her studies.

I would like to assure you that data collected from your organization and key informants will be kept confidential and made anonymous. Therefore, I would like to ask you to be as accurate and honest as possible in your responses when the student will be collecting her data. She may also ask to see some of your records if available.

I am thanking you in advance for your cooperation in assisting the above captioned student.

Yours faithfully,

**KELVIN MBIZI TEMBO**

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CC:
Salule Masangwi (PhD) - WASHTED Director

**Appendix G:    Introduction letter**

**Appendix H:    Calculations for IGA earnings at Kuntiyani and Umodzi**
**CBOs (The data was extracted from the CBOs IGA accounts records)**

**1.0    Purchase and selling of solar lanterns for Kuntiyani and Umodzi CBOs**
**CSPV systems:-**
*(a)    Kuntiyani CBO*

Capital                                                            =  MK230,000.00
Purchased of solar lanterns by cash (Expenditure)  =  MK30,350.00
Sale of solar lanterns by cash (No date) (Income)  =  MK84,350.00
Therefore solar lanterns earnings =  (income - expenditure)
=  MK (84,350 - 30,350)
=  MK54,000.00

*(b)    Umodzi CBO*

**Table H1:-** Purchase and selling of solar lanterns for Umodzi  CBOs CSPVsystems

| Date | Description | Expenditure (MK) | Income (MK) |
|---|---|---|---|
| Capital = 400,000.00 | | | |
| June, 2014 | Purchase of solar lanterns | 400,000.00 | |
| | Sale of solar lanterns | | 418,000.00 |
| **Solar lanterns earnings = Income - Expenditure** **= MK (418,000.00 - 400,000.00 )** **= MK18,000.00** | | | |
| 09th September, 2015 | Purchase of solar lanterns | 236,100.00 | |
| | Sale of solar lanterns | 320,100.00 | |
| **Solar lanterns earnings = Income – Expenditure** **= MK (320,100.00 - 236,100.00 )** **= MK84,000.00** **Average solar lanterns earnings for the months of June and September** **= MK (84,000.00 + 18,000.00) /2** **= MK51,000.00** | | | |

IGA earnings from solar lanterns for Kuntiyani and Umodzi CBOs in one month are   MK54,000.00 and MK51,000.00 respectively, therefore in 1 year (2 months):
Kuntiyani CBO = MK54,000 x 12 = **MK648,000.00**
Umodzi CBO    = MK51,000 x 12 = **MK612,000.00**

**2.0    IGAs directly linked to the CSPV systems:-**
**2.1    Phone charging:-**
Number of phones per day = 20
Cost of a phone charging              = MK30.00
Total income per day                  = MK600.00
If in 1-day total income from phone charging is MK600.00 therefore in a 6 days week

(Monday to Saturday) =   6 days x MK600.00
                              1 day

=  MK3,600.00

If in 1-week total income from phone charging is MK3,600.00
Therefore in 1 month which is 4 weeks =   4 weeks x MK3,600.00
                                              1 week

$=$  MK14,400.00

If in 1-month total income from phone charging is MK14,400.00

Therefore in 1-year which is 12 months =   $\frac{12 \text{ months x MK14,400.00}}{1 \text{month}}$

**= MK172,800.00**

**2.2  TV shows (TV is shown once a week (every Saturday):-**
Number of people per show in a day = 20
Cost per person per show            = MK100.00
Total income per TV show           = MK2,000.00
Total income per week =  MK2,000.00 and 1 month there are 4 weeks
Therefore, total income from TV is shown in 1 month = 4 x MK2,000.00 =  MK8,000.00
Total income in 1 year (12 months) = MK8,000 x 12
**=  MK96,000.00**

**2.3   Drawing water:-**
*2.3.1   Households*
Number of households = 170
Contribution per household per year = MK300.00
Total income per year from households =  170 x MK300.00
**= MK51,000.00**

*2.3.2      Staff houses*
(a)  4 staff houses at Kuntiyani CBO pay MK1,200.00 every month for the water.
   Total income per month for the 4 staff houses = MK1,200.00 x 4
                                            = MK4,800.00

   Total income per year (12 months) for the 4 staff houses = MK4,800.00 x 12
                                            = MK57,600.00

(b)  1 staff house pays MK1,000.00 every month
   Total income per month for 1 staff house = MK1,000.00 x 1
                                            = MK1,000.00

   Total income per year (12 months) for the staff houses = MK1,000.00 x 12
                                            = MK12,000.00

   Total income per year for 5 staff houses  = MK (57,600 + 12,000.00)
**= MK169,600.00**

Total income per year for drawing water (community and staff houses)
= MK (69,600.00 + 51,000.00)
**= MK120,600.00**

Therefore total IGA earnings at Kuntiyani = MK (648,000.00 + 172,800.00 +
                                    96,000.00 + 120,600.00)
**= MK1,037,400.00**

**3.0    Operation and maintenance costs in year 2014 / 2015**
**3.1  Kuntiyani CBO CSPV system:**
*(a) Operation costs*
   1.  Payment of security guard is MK7,500.00 per month
      Therefore in 1 year   = MK7,500 x 12
                        = MK90,000.00

2.  TV screen hiring from a teacher (the teacher gets 25% from TV shows earnings)

$$= \underline{\text{MK96,000.00 x 25}}$$
$$100$$

$$= \text{MK24,000.00}$$

*(b) Maintenance cost*
Replace water taps at a cost of Mk10,000.00 (The amount includes cost of new water taps and transport no labour cost because one of the teacher managed to fix the new taps).

Therefore total operation and maintenance costs
$$= \text{MK } (90,000.00 + 24,000.00 + 10,000.00)$$
$$= \text{MK124,000.00}$$

### 3.2   Umodzi CBO CSPV system:-
Operation costs = 0 (security guard is paid on government pay roll)
Maintenance costs (labour, transport and subsistence allowances)
  (a)  Repair of inverter at primary school  = MK45,000.00
  (b)  Replacement of inverter at CDSS     = MK165,000.00
  (c) Cost of inverter in September, 2014 = MK90,000.00
      Maintenance costs only = Replacement of inverter at CDSS – cost of inverter
                                in September, 2014.

   (The inverter was replaced at no cost because it was burnt within the warranty
   period thus less than 1 year)

$$= \text{MK } (165,000.00 – 90,000.00)$$

$$= \text{MK75,000.00}$$
Therefore, total maintenance costs   =   MK (45,000.00 + 75,000.00) = MK120,000.00

### 4.0    Net IGA earnings:-
### 4.1   Kuntiyani CBO:-
Net IGA earnings   = Total IGA earnings - operational costs and maintenance costs
$$= \text{MK } (1,037,400.00 – 124,000.00)$$
**= MK913,400.00**

### 4.2   Umodzi CBO:-
Net IGA earnings = Total IGA earnings - Maintenance costs
$$= \text{MK } (612,000.00 -120,000.00)$$
**= MK492,000.00**
### 5.0   Final end-customer prices for essential components in 2016 using the compounding formula:-
Future value (FV) = Investing Capital (K) x $(1 + i)^n$
Where $(1 + i)^n$ = compounding factor (CF)
Where i = inflation rate
        n = number of years and in this case end of one year of doing IGAs
Taking November, 2016 inflation rate of 19.9% for non-food items (NSO, 2016).
Therefore CF = (1 + 0.19)
              = 1.199

Therefore **December, 2016** replacement component final end-customer
   prices = CF x  Initial final end-customer prices   December, 2015 (Refer to Table
   E2.

**5.1 Battery-based itemised final end-customer prices of essential replacement components for December, 2016:-**

*(a)*     *PV module (100W)*
       = MK (1.199 x 95,000.00)
    = **MK113,905.00**

*(b)*     *Battery (96Ah)*
    = MK (1.199 x 135,000.00)
    = **MK161,865.00**

*(c)*     *Inverter*
    = MK (1.199 x 99,000.00)
    =**MK118,701.00**

*(d)*     *Charge controller  (20A)*
    = MK (1.199 x 49,000.00)
    = **MK58,751.00**

**5.2 Water pumping system itemised final end-customer prices of essential replacement components for December, 2016:-**

*(a)*     *PV modules (80W)*
    = MK (1.199 x 81,000.00)
    **= MK97 119.00**

*(b)*     *Grundfos submersible pump*
    = MK (1.199 x 1,500,000.00)
    **= MK1,798,500.00**

*(e)*     *Pump controller*
    = MK (1.199 x 450,000.00)
    **= MK539,550.00**

**Table H2:-** Discount Factor Table
Discount Factor (p.a) For a range of Discount Rates
Present value of $1 in the future at Discount Rate r%

| Year | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% | 11% | 12% | 13% | 14% | 15% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0.9709 | 0.9615 | 0.9524 | 0.9434 | 0.9346 | 0.9259 | 0.9174 | 0.9091 | 0.9009 | 0.8929 | 0.8850 | 0.8772 | 0.8696 |
| 2 | 0.9426 | 0.9246 | 0.9070 | 0.8900 | 0.8734 | 0.8573 | 0.8417 | 0.8264 | 0.8116 | 0.7972 | 0.7831 | 0.7695 | 0.7561 |
| 3 | 0.9151 | 0.8890 | 0.8638 | 0.8396 | 0.8163 | 0.7938 | 0.7722 | 0.7513 | 0.7312 | 0.7118 | 0.6931 | 0.6750 | 0.6575 |
| 4 | 0.8885 | 0.8548 | 0.8227 | 0.792 | 0.7629 | 0.7350 | 0.7084 | 0.6830 | 0.6587 | 0.6355 | 0.6133 | 0.5921 | 0.5718 |
| 5 | 0.8626 | 0.8219 | 0.7835 | 0.7473 | 0.7130 | 0.6806 | 0.6499 | 0.6209 | 0.5935 | 0.5935 | 0.5428 | 0.5194 | 0.4972 |
| 6 | 0.8375 | 0.7903 | 0.7462 | 0.7050 | 0.6663 | 0.6302 | 0.5963 | 0.5645 | 0.5346 | 0.5066 | 0.4803 | 0.4556 | 0.4323 |
| 7 | 0.7599 | 0.7107 | 0.6651 | 0.6227 | 0.5835 | 0.5470 | 0.5132 | 0.4817 | 0.4523 | 0.4251 | 0.4251 | 0.3996 | 0.3759 |
| 8 | 0.7894 | 0.7307 | 0.6768 | 0.6274 | 0.5820 | 0.5403 | 0.5019 | 0.4665 | 0.4339 | 0.4039 | 0.3762 | 0.3506 | 0.3269 |
| 9 | 0.7664 | 0.7026 | 0.6446 | 0.5919 | 0.5439 | 0.5002 | 0.4604 | 0.4241 | 0.3909 | 0.3606 | 0.3329 | 0.3075 | 0.2843 |
| 10 | 0.7441 | 0.6756 | 0.6139 | 0.5584 | 0.5083 | 0.4632 | 0.4224 | 0.3855 | 0.3522 | 0.3220 | 0.2946 | 0.2697 | 0.2472 |

**Discount factor = 1 / (1+r)$^n$ where r = Discount rate and n = length of time**
**(Extracted from The Farmers Forest: Multipurpose Forestry for Australian Farmers p121)**

**6.0    Net Present Value Calculations**
Constant annual Net IGA earnings for 10 years
Discounted factor = 15% (obtained from the Discount Factor Table extract attached)

**Table H3:-** Net Present Value of Kuntiyani CBO CSPV system

| Kuntiyani CBO CSPV system | | | |
|---|---|---|---|
| | **Net cash flow** | **Discounted factor** | **Present value** |
| **Period (Year)** | **MK'000** | **15%** | **MK'000** |
| 0 | (32,000,000.00) | 1.0000 | (32,000,000.00) |
| 1 | 913,400 | 0.8696 | 794,292.64 |
| 2 | 913,400 | 0.7561 | 690,621.74 |
| 3 | 913,400 | 0.6575 | 600,560.50 |
| 4 | 913,400 | 0.5718 | 522,282.12 |
| 5 | 913,400 | 0.4972 | 454,142.48 |
| 6 | 913,400 | 0.4323 | 394,862.82 |
| 7 | 913,400 | 0.3759 | 343,347.06 |
| 8 | 913,400 | 0.3269 | 298,590.46 |
| 9 | 913,400 | 0.2843 | 259,679.62 |
| 10 | 913,400 | 0.2472 | 225,792.48 |
| Net Present Value | | | -27,422,855.00 |

In Table H3, MK32,000,000.00 is the capital (investment) cost of the installed CSPV system at Kuntiyani CBO. MK913,400.00 is the even net cash flow each year for a period of 10 years.

**Note:**    Present Value (PV) = Net cash flow x Discounted factor
Net Present Value   = Sum of PV (year 1 to year 10) – capital
(investment cost)
= MK (794,292.64 + 690,621.74 + 600,560.50 +
522,282.12 + 454,142.48 + 394,862.82 +
343,347.06 + 298,590.46 + 259,679.62 +
225,792.48 + 32,000,000.00)
= MK (4,584,171.92  - 32,000,000.00)
= **MK (-27,415,828.08)**

**Table H4:-** Net Present Value of Umodzi CBO CSPV system

| Umodzi CBO CSPV system | | | |
|---|---|---|---|
| | **Net cash flow** | **Discounted factor** | **Present value** |
| **Period (Year)** | **MK'000** | **15%** | **MK'000** |
| 0 | (13,000,000) | 1.0000 | (13,000,000) |
| 1 | 492,000 | 0.8696 | 427,843.20 |
| 2 | 492,000 | 0.7561 | 372,001.20 |
| 3 | 492,000 | 0.6575 | 323,490.00 |
| 4 | 492,000 | 0.5718 | 281,325.60 |
| 5 | 492,000 | 0.4972 | 244,622.40 |
| 6 | 492,000 | 0.4323 | 212,692.60 |
| 7 | 492,000 | 0.3759 | 184,942.80 |
| 8 | 492,000 | 0.3269 | 160,834.80 |
| 9 | 492,000 | 0.2843 | 139,875.60 |
| 10 | 492,000 | 0.2472 | 121,622.40 |

| Net Present Value | -10,530,749.40 |
|---|---|

In Table H4, MK13,000,000.00 is the capital (investment) cost of the installed CSPV system at Kuntiyani CBO. MK492,000.00 is the even net cash flow each year for a period of 10 years.

**Note:** Present Value (PV) = Net cash flow x Discounted factor

Net Present Value = Sum of PV (year 1 to year 10) - capital (investment) cost

$$= MK (427,843.20 + 372,001.20 + 323,490.00 +$$
$$281,325.60 + 244,622.40 + 212,692.60 +$$
$$184\ 942.80 + 160,834.80 + 139,875.60 +$$
$$121,622.40 + 32,000,000.00)$$
$$= MK (2,469,250.60\ - 13,000,000.00)$$
$$= \textbf{MK (-10,530,749.40)}$$